Critical Minerals & Mining

Figures current as of October 2026

The metals the modern economy is made of: the mines and why they take so long, the refining chokepoint, the producers' new leverage, the Western response, and the markets that price it all.

MODULE 1 — Foundations: What Makes a Mineral Critical

Goal: Establish the concept, the lists, and the market of 2026.

Criticality as importance times supply risk; the American, European, and Chinese lists; supply and concentration by mineral in one table; and the 2026 market in one view, from record copper to the Hormuz shock.

MODULE 2 — Mining Fundamentals

Goal: Explain how a mine works, what it costs, and why it takes so long.

Grade, tonnage, and the cost curve; the eighteen-year path from discovery to production; open pits, underground caves, brines, and leaching; the companies; and a copper mine's economics worked at three prices.

MODULE 3 — Processing and Refining: Where the Chokepoint Sits

Goal: Show that the constraint is the plant rather than the ore.

Mining and refining shares by mineral; why the West lost refining; and what a refinery costs, how long it takes, and why Chinese prices keep Western plants from being built.

MODULE 4 — Copper

Goal: Cover the metal the electric economy runs on.

Supply and demand by country; the price record to September 2026; the argument over whether a deficit is coming; the Congo's order, Grasberg, Cobre Panama, and Resolution; and a deficit worked.

MODULE 5 — Lithium

Goal: Cover the battery metal and its cycle.

Resources and production; brine, hard rock, and direct extraction; the 2022-26 price cycle and a mine worked through it; storage demand; and the producers' policies from Chile to Zimbabwe.

MODULE 6 — Nickel and Cobalt

Goal: Cover the two metals one country each controls.

Indonesia's two-thirds of nickel and its 2026 quota cut; the Congo's three-quarters of cobalt and its export quota; and the cobalt squeeze worked from both sides.

MODULE 7 — Graphite, Manganese, and the Battery-Chain Minerals

Goal: Cover the anode and the cathode's other inputs.

Graphite's Chinese licensing and the failed American duty case; nickel-rich against iron-phosphate cathodes; manganese, phosphate, and acid; and the arithmetic of a battery pack.

MODULE 8 — Rare Earths and China's Export Weapon

Goal: Cover the seventeen elements and the confrontation over them.

The magnet elements and their two-tier prices; the 2010 embargo of Japan; the April 2025 halt and the truce, extended in September 2026 to January 10, 2027; and the alternatives on an honest timeline.

MODULE 9 — The Strategic Minor Metals

Goal: Cover the metals with no substitutes and one supplier.

Gallium, germanium, antimony, tungsten, scandium, silver, and tin; the control calendar; tungsten's fivefold rise; and the defense exposure and the stockpile.

MODULE 10 — The Bulk Metals: Iron Ore, Bauxite, and Aluminum

Goal: Cover the largest-volume mined commodities.

Iron ore's triangle and Simandou's thirty-year road to first shipment; bauxite and Guinea; aluminum, China's cap, and the 2026 strikes on Gulf smelters; and what the bulk metals teach.

MODULE 11 — The Battery and Magnet Supply Chains

Goal: Trace the chains from mine to cell and magnet.

China's share at each step of the battery chain; the magnet chain from oxide to motor; and Korea, Japan, and the American rules that bar Chinese inputs.

MODULE 12 — Producer Power: The New Resource Nationalism

Goal: Cover the quotas, bans, and state venues producers now use.

The export-restriction regimes in one table; the doctrine of administered scarcity; why it works and where it fails; and what it does to prices and investment.

MODULE 13 — The American Response

Goal: Map the US playbook and weigh it.

Price floors, equity stakes, offtakes, Project Vault, tariffs, and export controls; the Pentagon's 2025 deal with MP Materials; the argument over the state as investor; and what has actually been built.

MODULE 14 — Allies, Rivals, and the Global South

Goal: Cover Europe, Japan, Australia, Canada, India, and the producers' deals.

Europe's targets and its 2025 plan; Japan's stockpiles and China's 2026 ban; Australia's reserve; the Global South's leverage; and the coordination problem.

MODULE 15 — Recycling, Substitution, and Demand Destruction

Goal: Assess the ways out of dependence that do not involve mines.

Recycling rates by metal; black mass and its economics; iron-phosphate and sodium-ion cells against nickel and cobalt; magnets without rare earths; and how squeezes undo themselves.

MODULE 16 — Prices, Markets, and Finance

Goal: Explain how minerals are priced and paid for.

Exchanges against assessed prices; the 2022 nickel crisis; the 2026 bull market and the copper split between New York and London; and who pays for mines.

MODULE 17 — Environment, Communities, and the Social License

Goal: Cover the constraints that stop mines.

Water and tailings; communities and consent, from Oak Flat to Cobre Panama; and the argument between faster permits and consent.

MODULE 18 — Where Things Stand, and What to Watch

Goal: Assemble the argument and name the dates.

The argument on a page, the lesson of six turning points, five contradictions, a dated watch list, and a last word.

A note on the ground. The minerals trade is argued over as much as it is measured. The same copper forecast is read as a coming shortage by miners and banks and as a balanced market by the producers' study group. A price floor is called security by the government that pays it and a subsidy by its critics. A mine is a jobs program to one side and a sacred site to the other. The course gives the figures as the agencies, exchanges, and price reporters publish them. It makes each side's case as its advocates make it and marks disputed figures as disputed. Figures are dated to October 2026, and the table before Module 1 names the source and release of each.

Key Numbers, as of October 2026

The production, prices, and shares the course relies on

Measure	Figure	Period	Source and release
Copper price, London	$14,614.50 a tonne (three-month contract), about 2% below the record of $14,875 set on September 10, 2026. The 2025 average was just under $10,000	October 8, 2026	London Metal Exchange (LME)
Copper price, New York	About $6.66 a pound, about $14,700 a tonne	October 9, 2026	COMEX, the metals exchange of CME Group
Copper output	23 million tonnes (Mt) mined: Chile 5.3, the Democratic Republic of the Congo (DRC) 3.2, Peru 2.7. About 29 Mt refined, China 14 Mt of it	2025 (estimated)	US Geological Survey (USGS), *Mineral Commodity Summaries 2026* (January 2026)
Copper balance	Surplus of 96,000 tonnes in 2026 and 377,000 in 2027 (study group). Deficits of about 330,000 to 600,000 tonnes in 2026 (three banks)	2026-27 forecasts	International Copper Study Group (ICSG), April 2026; J.P. Morgan, UBS, and Morgan Stanley (June 2026)
Lithium output	About 290,000 tonnes of lithium content, roughly 1.5 Mt of lithium carbonate equivalent (LCE): Australia 32%, China 21%, Chile 19%, Zimbabwe 10%, Argentina 8%	2025, excluding the US	USGS, *Mineral Commodity Summaries 2026*
Lithium carbonate price	127,750 yuan a tonne ($19,025), battery grade, ex-works China, down 20.8% in the quarter. The 2025 average was about $9,000	End of September 2026	Benchmark Mineral Intelligence, *Q3 2026 Lithium Price Review* (October 2, 2026); USGS
Nickel	3.9 Mt mined, Indonesia 2.6 Mt (67%). LME price $15,700 a tonne, against a 2025 average of $15,000	2025; October 9, 2026	USGS, *Mineral Commodity Summaries 2026*; LME
Indonesia's nickel ore quota	260-270 million wet tonnes approved for 2026, against 379 million for 2025	2026	Indonesia's Ministry of Energy and Mineral Resources (February 12, 2026)
Cobalt	310,000 tonnes mined: the DRC 230,000 (73%), Indonesia 44,000 (14%), shares of the USGS's unrounded world total. The DRC's export quota is 96,600 tonnes a year for 2026 and 2027	2025; 2026-27	USGS, *Mineral Commodity Summaries 2026*; the DRC's strategic minerals authority (ARECOMS), October 2025
Cobalt prices	Hydroxide $17.25 a pound ($38,030 a tonne of contained cobalt), down 31% in the quarter. Metal held above $25 a pound through August, then fell about 11%	Third quarter of 2026	Benchmark, *Q3 2026 Cobalt Price Review* (September 30, 2026)
Rare-earth mining	390,000 tonnes of rare-earth oxide (REO): China 270,000 (69%), the US 51,000 (13%), Australia 29,000, Myanmar 22,000	2025 (estimated)	USGS, *Mineral Commodity Summaries 2026*
Rare-earth refining and magnets	China 85% of refining, down from over 90% in 2023, and 70% projected for 2035 if planned plants are built. China makes about 94% of sintered magnets	2025; 2035	International Energy Agency (IEA), *Global Critical Minerals Outlook 2026* (July 16, 2026)
Rare-earth prices	Neodymium-praseodymium (NdPr) oxide 729,500 yuan a tonne in China ($108.7 a kilogram); $106.5 a kilogram outside China, below the Pentagon's $110 floor. Dysprosium oxide $3,500 a kilogram in Europe, about 16 times China's price	September 2026	Benchmark, *Q3 2026 Rare Earths Price Review* (September 25, 2026)

Measure	Figure	Period	Source and release
Graphite	1.8 Mt of natural graphite mined, China 1.4 Mt	2025 (estimated)	USGS, *Mineral Commodity Summaries 2026*
Gallium and tungsten	Gallium: about 900 tonnes of primary output, nearly all Chinese. Tungsten: 85,000 tonnes mined, China 67,000 (79%); the price of ammonium paratungstate (APT) averaged $675 per metric tonne unit (mtu) in 2025 and about $3,245 in the second quarter of 2026	2025; 2026	USGS, *Mineral Commodity Summaries 2026*; Fastmarkets, reported by Masan High-Tech Materials (July 29, 2026)
Aluminum	74 Mt of primary metal, China 45 Mt (61%). LME cash price $3,134 a tonne, after a four-year high of about $3,665 in mid-April 2026	2025; October 6, 2026	USGS, *Mineral Commodity Summaries 2026*; LME
Iron ore	$90.68 a tonne for ore of 62% iron delivered to China, down 14% in a year	October 9, 2026	The benchmark 62% fines price, via Trading Economics
The market as a whole	Investment in critical-mineral supply fell 9% in 2025. The leading refining country held about 72% of capacity on average across the key energy minerals. Public finance commitments quadrupled to $65 billion over 2023-25	2025	IEA, *Global Critical Minerals Outlook 2026*
China's export controls	The October 2025 expansion is suspended under the truce, which was extended on September 24, 2026 from November 10 to January 10, 2027; the April 2025 licensing of seven rare earths stays in force. The ban on gallium, germanium, and antimony exports to the US is suspended until November 27, 2026, a date the extension's announcements did not mention	As of October 2026	China's Ministry of Commerce (November 2025 announcements; statement of September 28, 2026)

Tonnes are metric throughout; one tonne is 1.10 US short tons, and one pound is 0.4536 kilograms. Prices move daily; the third column gives the dates of the figures, not of this course. USGS figures for 2025 are its January 2026 estimates.

Module 1 — Foundations

What Makes a Mineral Critical

Recommended Reading / Reference

Book: Ernest Scheyder, *The War Below: Lithium, Copper, and the Global Battle to Power Our Lives* (2024)

Reference: IEA, *Global Critical Minerals Outlook 2026* (July 16, 2026); USGS, *Mineral Commodity Summaries 2026* (January 2026); the Interior Department's final 2025 List of Critical Minerals (November 6, 2025); the European Union's Critical Raw Materials Act (2024)

1a. The Concept

A mineral is critical when two things are true at once: it matters to the economy, to defense, or to a technology with no ready substitute, and its supply is at risk. The risk comes from concentration, when production or processing sits in a few places, a few companies, or one country that may decline to sell, and neither condition alone qualifies.

Iron ore matters enormously but comes from many countries, so it is not on the lists. Gallium is made in tiny amounts, about 900 tonnes a year, and most industries would never notice its absence, but China makes nearly all of it and gallium-nitride radars and many power chips depend on it, so it is critical.

Criticality is a matrix of importance against risk, and its contents move with technology and politics. Cobalt mattered less as battery makers learned to use less of it, then its risk rose when the Congo restricted exports in 2025, and the rare earths went from a curiosity in 2000 to a crisis in 2010 and a weapon in 2025.

1b. The Lists

List	Size	Notable inclusions	Purpose
The US List of Critical Minerals, final 2025 version (published November 6, 2025)	60 minerals	Ten additions: copper, silver, uranium, silicon, rhenium, potash, phosphate, metallurgical coal, lead, and boron. Already listed: the rare earths, lithium, cobalt, nickel, graphite, gallium, germanium, antimony, and tungsten	Eligibility for federal support, faster permitting, stockpile purchases, and trade actions
The European Union's Critical Raw Materials Act (in force May 2024)	34 critical, 17 strategic	Bauxite and aluminum, copper, nickel, lithium, cobalt, graphite, the magnet rare earths, gallium, germanium, tungsten. Iron ore and gold are not on it	Targets for 2030: 10% of the EU's needs mined at home, 40% processed, 25% recycled, and no more than 65% of any strategic material from one outside country
The IEA's key energy minerals	Six, plus a wider set	Copper, lithium, nickel, cobalt, graphite, and the rare earths; also aluminum, manganese, silicon, and the strategic minor metals	Tracking the energy transition's material needs and the risks to them
China's export-control list, the mirror	A growing list	Gallium and germanium (2023), graphite (2023), antimony (2024), tungsten and four other metals (February 2025), seven rare earths (April 2025), and five more rare earths with the technology to process them (October 2025, suspended). Silver exports were licensed for 2026-27	The materials China can withhold

1c. Supply at a Glance

Mineral	Output (2025)	Leading producer	Main uses	Where the risk sits
Copper	23 Mt mined; about 29 Mt refined	Chile, 23% of mining; China, 48% of refining	Wiring, grids, motors, buildings, vehicles	Aging mines and falling grades; smelting concentrated in China
Lithium	About 290,000 tonnes of lithium, roughly 1.5 Mt LCE	Australia, 32% of mining	Batteries, most of demand	Chemical refining concentrated in China
Nickel	3.9 Mt	Indonesia, 67%	Stainless steel, most of demand; batteries	One country's quotas
Cobalt	310,000 tonnes	The DRC, 73%	Batteries, superalloys, magnets	One country's export quota; refining mostly Chinese
Graphite	1.8 Mt natural, plus synthetic	China, about four-fifths of natural	Battery anodes, steel-furnace electrodes, refractories	China makes nearly all battery anode material; export licensing
Rare earths	390,000 tonnes of REO	China: 69% of mining, 85% of refining, about 94% of magnets	Magnets for motors, turbines, and weapons	Licensing since April 2025; the heavy elements almost all Chinese
Gallium, germanium, antimony, tungsten	Small: from hundreds to tens of thousands of tonnes	China, dominant in each	Chips, optics, ammunition, cutting tools	Chinese export controls since 2023
Aluminum	74 Mt	China, 61%	Power lines, vehicles, packaging, buildings	China's output cap; the 2026 strikes on Gulf smelters

USGS, *Mineral Commodity Summaries 2026*; IEA, *Global Critical Minerals Outlook 2026*. Mt = million tonnes; LCE = lithium carbonate equivalent; REO = rare-earth oxide.

1d. The 2026 Market in One View

The IEA's *Global Critical Minerals Outlook 2026*, published on July 16, describes a market that turned: critical-mineral prices rebounded in 2025 and early 2026 after several years of decline, and a raft of new export restrictions amplified the rise. Investment in new supply nonetheless fell 9% in 2025, ending several years of growth.

Concentration edged higher, because over two years the top refiners, Indonesia for nickel and China for the other key minerals, supplied more than three-quarters of all growth in refined supply, and for manganese, nickel, and graphite they supplied virtually all of it. Governments responded with money, and public finance commitments to mineral projects more than quadrupled over 2023-25, to $65 billion.

The prices show the turn: LME copper set a record of $14,875 a tonne on September 10, 2026, and lithium carbonate rose by about two-thirds in dollar terms in the first five months of the year before falling back. Cobalt more than doubled on the Congo's quotas, and tungsten's price rose about fivefold from its 2025 average as China's controls bit.

A war added a chokepoint that no list had named. The conflict with Iran that began on February 28, 2026 closed and then crippled the Strait of Hormuz, and on March 28 Iranian strikes hit two of the Gulf's largest aluminum smelters, in a region that makes about 9% of the world's primary aluminum. At least half of the world's seaborne sulfur also passes the Strait, and sulfur is burned to make the sulfuric acid that leaches

copper, refines lithium, and extracts nickel. By May sulfur prices had risen more than 50%, and acid prices had more than doubled in some regions.

The market's instruments are increasingly quotas, licenses, floors, and reserves rather than prices, which is the theme of Modules 12 through 14, and in two years the subject has moved from a question of supply for the energy transition to a question of geopolitics.

Module 1 Key Points

Foundations

• A mineral is critical when it matters and its supply is at risk; gallium, about 900 tonnes a year, nearly all Chinese, qualifies.

• The US list grew to 60 minerals in November 2025, adding copper and silver; China's export-control list is its mirror.

• Concentration is the pattern: Indonesia mines 67% of nickel, the Congo 73% of cobalt, and China refines 85% of rare earths.

• Prices rebounded in 2025-26 and export restrictions amplified them, yet investment in new supply fell 9% in 2025.

• The 2026 Iran war struck Gulf aluminum smelters and choked sulfur, the raw material for the acid that leaches copper and nickel.

Module 1 Quiz

Check Your Understanding

1. What two conditions together make a mineral critical?

A) It matters, and its supply is at risk
B) It is rare in the earth's crust and costs more per kilogram than most metals
C) It trades in high volume on an exchange and goes into batteries or magnets
D) Its price has doubled within a year, and the US imports most of what it uses

2. Why is gallium on the critical lists while iron ore is not?

A) Iron ore no longer has industrial uses that matter
B) China makes nearly all of it, and radar and power chips need it
C) Gallium is far rarer in the earth's crust than iron, and none of it can be recycled
D) The European Union sets the lists, and it has no gallium deposits of its own to develop

3. According to the IEA's July 2026 Outlook, what happened to investment in new supply in 2025?

A) It doubled on record copper prices
B) It rose slightly, in step with prices
C) It held flat for a third straight year while prices rose by about a third across all the energy minerals
D) It fell 9%, ending several years of growth

4. How did the 2026 war with Iran reach the minerals markets?

A) Iran halted its exports of copper concentrate
B) Through the price of diesel for haul trucks alone
C) Strikes hit Gulf aluminum smelters, and the closed Strait choked the sulfur used to make leaching acid
D) Shipping insurers stopped covering bulk carriers in the Pacific

5. Which list does the module call the mirror of the Western lists?

A) The European Union's list of strategic raw materials under its 2024 act
B) China's export-control list
C) The International Energy Agency's six key energy minerals
D) Japan's list of rare metals held in its national stockpile

Module 2 — Mining Fundamentals

How a Mine Works, What It Costs, and Why It Takes So Long

Recommended Reading / Reference

Reference: S&P Global Market Intelligence's studies of mine lead times (2024); company technical reports filed under Canada's National Instrument 43-101 (NI 43-101) and the Code of Australia's Joint Ore Reserves Committee (JORC); USGS, *Mineral Commodity Summaries 2026*; the cost curves of Wood Mackenzie and CRU

2a. Grade, Tonnage, and Cost

A mine is a machine for concentrating something the earth has scattered, and ore grade, the share of the rock that is the target metal, decides most of its economics. Copper ore averages roughly 0.6% copper by industry estimates, and grades at the oldest Chilean mines have fallen for decades. Gold ore runs one to a few grams a tonne, lithium brine a few hundred to a couple of thousand parts per million, and rare-earth ore a few percent.

Lower grade means more rock moved, and more energy, water, and waste for every tonne of metal, which is why the copper industry's costs rise decade by decade and why a discovery's grade matters more than its size.

Costs divide into capital, which builds the pit, the plant, the power and water lines, and the tailings dam and runs from $1 billion to more than $10 billion for a large project, and operating cost, which moves and processes the rock. The industry's economics are its cost curve, a ranking of every mine from cheapest to dearest: in normal times the price settles near the cost of the marginal mine, and in a shortage it runs far above it.

2b. The Timeline

Stage	What happens	Duration	Attrition and risk
Exploration	Geology, sampling, and drilling to find and outline a deposit	3-10 years	Only a small fraction of prospects ever becomes a mine
Studies	A resource estimate, engineering, and the 'bankable' feasibility study that lenders require	2-4 years	Many projects stall at this stage
Permitting	Environmental review, water rights, consultation with communities and indigenous nations, land access	2-10 years; commonly 7-10 in the US	Litigation and opposition stop many; Resolution Copper filed its plan in 2013 and received its land in March 2026
Financing	Equity, debt, streaming deals, offtake contracts, state support	1-2 years	Markets were closed to junior miners in 2023-25
Construction	The mine, the plant, tailings storage, power, roads, and often a port	2-5 years	Large cost overruns are common
Ramp-up and production	Commissioning, then decades of operation	1-2 years to full rate	Grades decline; expansions follow

Stage	What happens	Duration	Attrition and risk
Closure	Reclamation and the care of tailings for decades or longer	Decades	Often underfunded: Panama's commission priced closing Cobre Panama at $2.6-3.4 billion over 17-19 years
Total: discovery to production		Nearly 18 years on average for mines that started in 2020-23	The reason supply cannot answer a price signal within a decade

S&P Global Market Intelligence (2024); company and government disclosures.

S&P Global found that mines which began production in 2020-23 took nearly eighteen years on average from discovery, and the wait is longest where the rule of law and public consultation are strongest. Resolution Copper in Arizona filed its plan of operations in 2013 and received title to its land only on March 16, 2026, with litigation still running.

The consequence is the central fact of every mineral market: supply cannot respond to price within a decade. A demand shock produces a price spike and the spike an investment wave, but the new supply arrives after the price has collapsed, as lithium's did in 2023-25. The industry's history is that cycle repeated, and the energy transition's problem is that its demand curves do not wait for it.

2c. The Methods

Method	Used for	How	Note
Open pit	Copper, iron ore, gold, hard-rock lithium, rare earths, bauxite	The ore body is blasted and hauled out in benches by trucks carrying up to 400 tonnes. The largest pits, Bingham Canyon, Escondida, and Chuquicamata, are about a kilometer deep	The cheapest per tonne of rock, with the largest footprint and the most waste
Underground and block caving	High-grade copper, gold, zinc, nickel; deep, low-grade bodies	Shafts and ramps; block caving undercuts an ore body so it collapses under its own weight (Grasberg, El Teniente, Oyu Tolgoi, Resolution)	A rising share as pits deepen. A mud rush halted Grasberg in September 2025, and a collapse at El Teniente killed six workers on July 31, 2025
Brine evaporation	Lithium in Chile and Argentina; potash	Brine is pumped to ponds and evaporated for 12-18 months, then lithium carbonate is precipitated	Low cost and slow; disputes over water
Direct lithium extraction (DLE)	Lithium from brines, oilfield water, and geothermal fluid	Sorbents or membranes pull lithium out in hours, without ponds	Small but rising, in Arkansas's Smackover formation and Argentina; the technology bet
Leaching and solvent extraction-electrowinning (SX-EW)	Oxide copper, uranium, gold; nickel laterites by high-pressure acid leaching (HPAL)	Acid or cyanide percolates through heaps or is injected into the deposit, and the metal is recovered by electrolysis	SX-EW yields about 22% of mined copper. It runs on sulfuric acid, which tied it to the 2026 sulfur shock
Artisanal and small-scale	Cobalt, gold, tin, tantalum, mica	Hand-dug, often informal	Small by volume and large by controversy: child labor and deadly accidents

Method	Used for	How	Note
Deep-sea nodules	Nickel, cobalt, copper, and manganese on the Pacific floor's Clarion-Clipperton Zone	Nodules the size of potatoes are collected from 4,000-5,500 meters	Not yet commercial. The National Oceanic and Atmospheric Administration (NOAA) found The Metals Company's US application compliant in 2026; a permit could come in early 2027. The International Seabed Authority (ISA) has no final rules

Industry and government sources; the SX-EW share is Benchmark's estimate (May 2026).

2d. The Companies

Company	Base	Main commodities	2025-26
BHP	Australia	Iron ore, copper (Escondida; Resolution, with Rio Tinto), potash; nickel suspended in 2024	Its executives attended the White House minerals roundtable of August 7, 2026
Rio Tinto	Britain and Australia	Iron ore (the Pilbara; Simandou), aluminum, copper (Oyu Tolgoi, Kennecott, Resolution), lithium (Arcadium, bought in 2025)	Walked away from merger talks with Glencore on February 5, 2026; Simandou's first ore shipped in November 2025
Glencore	Switzerland	Copper, cobalt in the Congo, zinc, coal; a commodity trader as well as a miner	Among the Congo's two largest cobalt producers
Freeport-McMoRan	US	Copper (Grasberg in Indonesia; Morenci; Cerro Verde in Peru), gold, molybdenum	Grasberg's block cave restarted in 2026 and is due near full output by the end of 2027
Codelco	Chile (state-owned)	Copper	About 1.33 Mt in 2025; six dead at El Teniente in July 2025; a lithium partnership with SQM since December 29, 2025
Vale	Brazil	Iron ore, nickel, copper	Still paying for the 2019 Brumadinho dam collapse
Zijin, CMOC, MMG, and Ivanhoe	China, China, China, Canada	Copper and cobalt abroad, from the Congo to Peru to Serbia	China's miners are the fastest-growing; CMOC is the largest cobalt producer; Ivanhoe runs Kamoa-Kakula with Zijin
Albemarle, SQM, Ganfeng, Tianqi, Pilbara Minerals	US, Chile, China, China, Australia	Lithium	The survivors of the 2023-25 price bust
Lynas and MP Materials	Australia; US	Rare earths	The largest separators outside China; MP's 2025 Pentagon deal (Module 13)
State capital: Codelco, Ma'aden, Gécamines, China Minmetals, Chinalco	Chile, Saudi Arabia, the DRC, China	Everything	The return of the state as owner and financier

Worked example — A Copper Mine's Economics

A new open-pit copper mine in Chile holds 800 million tonnes of ore at 0.5% copper: 4 million tonnes of contained metal, of which about 3.5 million can be recovered. It costs $6 billion to build, counting the plant, the pit, a desalination line for water, and power. It then produces 150,000 tonnes of copper a year for 23 years at an all-in sustaining cost of $2.80 a pound, about $6,200 a tonne, which puts it in the industry's third quartile because its grade is low.

The price decides the rest, and the returns here are before tax. At about $8,500 a tonne, near the 2023 average, the margin is $2,300 a tonne, or $350 million a year, so the mine pays back in seventeen years and returns 2-3%, below any company's cost of capital. At just under $10,000, the 2025 average, it earns $560 million a year, pays back in eleven years, and returns about 7%, which is marginal for a $6 billion bet that carries country, water, and price risk for a quarter-century.

At October 2026's $14,600 the margin is $8,400 a tonne and $1.26 billion a year, payback falls under five years, and the return rises to about 15-19%, depending on whether construction takes five years or two. The arithmetic explains why the industry has not built enough: the price that justifies a marginal mine is above what the market has usually paid, and a company that commits at a record price has historically watched the price halve before first production. The deficit is not a geological problem but a capital-allocation problem with an eighteen-year lag.

Module 2 Key Points

Mining Fundamentals

• Grade decides the economics: copper ore averages roughly 0.6%, and lower grade means more rock, energy, water, and waste per tonne.

• Mines that opened in 2020-23 took nearly 18 years from discovery, so supply cannot answer a price signal within a decade.

• Acid leaching and electrowinning yield about 22% of mined copper, which tied the mines to the 2026 sulfur shock.

• China's miners, CMOC, Zijin, and MMG, are the fastest-growing; Rio Tinto abandoned merger talks with Glencore in February 2026.

• A $6 billion mine returns about 7% at $10,000 copper and 15-19% at $14,600: the deficit is a capital problem.

Module 2 Quiz

Check Your Understanding

1. Why does ore grade matter more than the size of a deposit?

A) Size cannot be measured until the mine is open
B) High-grade deposits are exempt from environmental review in most countries
C) Lower grade means more rock, energy, and water per tonne
D) Regulators set royalties by deposit size, and large deposits pay far more of them

2. How long did mines that began production in 2020-23 take from discovery, according to S&P Global?

A) About six years
B) About thirty years
C) About ten years in every country
D) Nearly eighteen years on average, longest where consultation is strongest

3. Why did the 2026 sulfur shock matter to copper mining?

A) About 22% of mined copper is leached with acid made from sulfur
B) Smelters buy sulfur as fuel
C) Sulfur is blended into copper wire
D) Copper concentrate cannot leave through any Gulf port, and Chile's buyers depend on Gulf shipping

4. In the worked example, what does the mine return at the 2025 average copper price, just under $10,000?

A) About 2%
B) About 7% before tax
C) About 21%, enough to finance it on bank debt alone
D) A loss, since costs exceed that price for low-grade ore

5. What does the worked example conclude about the copper deficit?

A) It is a capital-allocation problem: the justifying price rarely lasts the eighteen years a mine takes
B) It is geological: the ore is running out
C) It will close once tariffs end
D) It reflects a shortage of geologists and engineers

Module 3 — Processing and Refining: Where the Chokepoint Sits

The Constraint Is the Plant, Not the Ore

Recommended Reading / Reference

Reference: IEA, *Global Critical Minerals Outlook 2026* (refining chapters); USGS, *Mineral Commodity Summaries 2026*; Benchmark Mineral Intelligence's supply-chain data; the Center for Strategic and International Studies' analyses of processing

3a. The Shares

Mineral	Mining: leader (share)	Refining: leader (share)	Refiners outside China (2026)
Copper	Chile (23%)	China (48% of refined output: 14 of 29 Mt)	Japan, Korea, India, Zambia, the DRC (rising); two primary smelters in the US
Lithium	Australia (32%)	China (about two-thirds of chemicals)	Chile, Argentina, Albemarle, Tesla's Texas refinery
Nickel	Indonesia (67%)	Indonesia, now the largest refiner, in mostly Chinese-owned plants; China second	Japan, Norway, Canada, Finland
Cobalt	The DRC (73%)	China (about three-quarters)	Finland, Canada, and the DRC's own refineries
Graphite	China (about four-fifths of natural graphite)	China (more than 90% of battery anode material)	Syrah (Louisiana), Posco (Korea), Novonix (Tennessee)
Rare earths	China (69%)	China (85% of refining; about 94% of sintered magnets)	Lynas (Malaysia), MP Materials (California), Solvay (France), Neo (Estonia)
Manganese, battery-grade sulfate	South Africa leads in ore	China (about 95%)	Planned plants only
Aluminum	Guinea and Australia lead in bauxite	China (61% of smelting)	India, Russia, Canada, the Gulf, Norway
Gallium; tungsten	—	China (nearly all gallium; about 85% of tungsten's APT)	Rio Tinto's gallium pilot in Quebec; Almonty in Korea

USGS, IEA, Benchmark, and S&P Global; shares rounded, for 2025. APT = ammonium paratungstate, tungsten's traded intermediate.

The minerals are mined in many places and refined in one. Copper comes from Chile, the Congo, and Peru and is smelted in China, lithium comes from Australia and is converted to chemicals in China, and nickel comes from Indonesia, where Chinese companies built the plants. Cobalt comes from the Congo and is refined in China, while graphite, rare earths, manganese sulfate, and most of the minor metals are both mined and processed in China.

The IEA's July 2026 Outlook puts numbers on the pattern: across the key energy minerals, the leading refining country held about 72% of capacity on average in 2025. Over two years the top refiners supplied more than three-quarters of all growth in refined supply, and for manganese, nickel, and graphite they supplied virtually all of it, while the alternatives in the table's last column are, with a few exceptions, small, new, or planned.

The ore is not the constraint; the plant that turns it into battery-grade chemical, separated oxide, or metal is, and the West spent thirty years letting those plants move to where they were cheapest to run.

3b. Why the West Lost Refining

Refining is dirty, energy-hungry, capital-heavy, and low-margin, a chemical industry rather than a mining one, and it left the West for the reasons other heavy industry did. China offered cheap coal power, lax environmental rules, state finance, land in industrial parks, and a domestic market that grew tenfold, while Western plants faced rising environmental costs and little policy interest, and their shareholders preferred to buy the refined product.

The rare-earth story is the template: the United States developed much of the separation chemistry and ran the world's largest mine at Mountain Pass, California, which stopped separating in 2002 after wastewater spills and Chinese price competition. China, whose leader Deng Xiaoping had said that 'the Middle East has oil, China has rare earths', subsidized the chain, tolerated the pollution, and came to set the price.

The same happened to graphite anodes, to manganese sulfate, and to gallium, a byproduct of Chinese alumina refining. It happened to nickel by a different route: Indonesia banned exports of nickel ore in 2020, and Chinese companies built most of the world's new nickel processing on Indonesian soil within five years.

3c. What a Refinery Costs and Takes

Facility	Typical capacity	Capital cost	Build time	Examples (2024-26)	The obstacle
Lithium hydroxide or carbonate plant	20-50 kt a year	$0.5-1.5B	3-5 years	Tesla (Texas, 2025); Posco (Korea, Argentina); Albemarle's paused expansion plans	Chinese prices below Western costs; acid costs since 2026
Copper smelter and refinery	300-500 kt	$2-4B	4-6 years	Freeport's Gresik (Indonesia); Adani (India, 2025); Kamoa-Kakula's on-site smelter (the DRC)	Treatment charges set at zero for 2026
Nickel high-pressure acid leach (HPAL) plant	50-100 kt	$1-3B	3-5 years	Indonesia's Chinese-built plants	Tailings; sulfur rose to 42% of costs in 2026
Cobalt refinery	10-20 kt	$0.3-0.8B	2-4 years	The DRC's domestic plants; Finland	Feed limited by the DRC's export quota
Graphite anode plant	20-50 kt	$0.5-1B	3-4 years	Syrah's Vidalia (Louisiana), Novonix (Tennessee), Posco (Korea)	Chinese anodes at about half the cost; the failed US duty case (Module 7)
Rare-earth separation plant	5-10 kt of oxides	$0.5-1B and up	4-6 years	MP (Mountain Pass), Lynas (Malaysia), Solvay (France), Iluka's Eneabba (Australia, due 2027)	Heavy-element chemistry; Chinese prices
Rare-earth magnet plant (neodymium-iron-boron, NdFeB)	1-10 kt	$0.2-0.7B	2-4 years	MP (Texas), eVAC (South Carolina), USA Rare Earth (Oklahoma), Neo (Estonia)	Chinese magnet prices; Chinese controls on equipment and know-how
Gallium or germanium recovery	Tens of tonnes	$0.05-0.2B	1-3 years	Rio Tinto (Quebec, gallium from alumina); 5N Plus (Utah, germanium from recycled feed)	Byproduct economics

Indicative ranges from company disclosures and industry analysts; kt = thousand tonnes.

A refinery costs less than a mine and takes less time: about $1 billion and four years for a lithium plant, $1 billion and five years for rare-earth separation, and $3 billion and five years for a copper smelter. It is where every Western program now aims, because it removes the chokepoint without a new mine: Australian lithium refined in Australia or the United States, rather than China, ends a dependence without a single new hole in the ground.

The obstacle in every row is the same: Chinese capacity, built with state finance and running at costs below the West's, sets prices at which a new Western plant cannot earn back its capital. Miners pay smelters a treatment charge to process their concentrate, and in December 2025 Chinese smelters and Chile's Antofagasta set the 2026 benchmark charge at zero, because China had built more smelting than there was ore to feed it. Rare-earth and anode prices are set by producers that do not need to profit.

That is why the American response (Module 13) turned from grants for mines to price floors, offtake contracts, and equity stakes in plants, and why a Western processing base that could survive a Chinese cutoff is a project for the 2030s.

Module 3 Key Points

Processing and Refining: Where the Chokepoint Sits

• Minerals are mined in many places and refined in one: the leading refiner held about 72% of capacity on average in 2025.

• China and Indonesia supplied over three-quarters of refined supply growth in two years, and virtually all of it for nickel and graphite.

• Refining left the West because it is dirty, energy-hungry, and low-margin; Mountain Pass stopped separating rare earths in 2002.

• A refinery costs less and takes less time than a mine, so Western programs now target plants rather than pits.

• Chinese overcapacity sets prices Western plants cannot match: copper's 2026 benchmark treatment charge was zero.

Module 3 Quiz

Check Your Understanding

1. What pattern does the module's table of shares show?

A) Minerals are scarce
B) The West has no deposits
C) Minerals are mined in many places and refined in one
D) Mining is more concentrated by country than refining is, at every step of every chain

2. What fee was set at zero in copper's 2026 benchmark?

A) The royalty Chile charges on every tonne of copper exported from its mines
B) The LME's warehouse rent for storing copper cathode in Asian locations
C) The freight rate for concentrate shipped from Peru to Chinese ports
D) The treatment charge

3. Who built most of Indonesia's nickel-processing capacity?

A) Chinese companies
B) Vale and Sumitomo, before the 2020 ban on ore exports
C) State refineries financed by Indonesia's sovereign wealth fund
D) Japanese trading houses that moved their smelters from New Caledonia

4. Why do Western programs now aim at refineries rather than mines?

A) Refineries need no permits
B) Mines are banned in most allied countries
C) Refining earns higher margins than mining does
D) A refinery costs less and takes less time, and it removes the chokepoint without a new mine

5. Why did the United States lose the rare-earth industry it once led?

A) Its ore ran out
B) A Chinese embargo closed it
C) Refining is dirty and low-margin, and China subsidized it
D) Japan bought Mountain Pass in the 1990s and moved the separation plant to Malaysia

Module 4 — Copper

The Metal the Electric Economy Runs On

Recommended Reading / Reference

Reference: The International Copper Study Group's forecasts (April 2026) and monthly bulletins; USGS, *Mineral Commodity Summaries 2026* (copper); IEA, *Global Critical Minerals Outlook 2026*; company reports from Codelco, Freeport-McMoRan, Ivanhoe Mines, and First Quantum; the DRC's order of June 29, 2026 on concentrate exports

4a. Supply and Demand

Country	Mined, 2025 (kt)	Share	Refined (kt)	Note
Chile	5,300	23%	1,700	Codelco (state-owned; 1.33 Mt in 2025), Escondida (BHP), Collahuasi; falling grades and desalinated water; a strike at Antofagasta's Centinela mine from October 7, 2026
The DRC	3,200	14%	2,800	Kamoa-Kakula (Ivanhoe and Zijin), Tenke Fungurume and Kisanfu (CMOC); the June 2026 order on concentrate
Peru	2,700	12%	340	Las Bambas (MMG), Cerro Verde, Antamina, Quellaveco; road blockades by communities
China	1,800	8%	14,000	The world's refiner and its largest consumer
Russia	1,300	6%	950	Norilsk; the new Udokan mine
United States	1,000	4%	850	Morenci and Bingham Canyon; two primary smelters; 57% of supply imported in 2025
Zambia	940	4%	270	A revival under new investment
Indonesia	710	3%	400	Grasberg's September 2025 mud rush cut output from 1,010 kt in 2024
Australia, Kazakhstan, Mexico, Canada, Poland	410-730 each	13% together	Various	Olympic Dam; Poland's KGHM; Canada's and Mexico's porphyry mines
World	23,000	100%	29,000	Refined output includes metal from scrap

USGS, *Mineral Commodity Summaries 2026* (estimates for 2025); kt = thousand tonnes.

Copper conducts electricity better than any metal but silver, which makes it the material of the electric economy, and most of it goes into wiring for buildings, grids, and machines. The growth is in what the energy transition and the data-center boom add: a battery-electric car uses roughly 80 kilograms of copper against about 20 for a gasoline car, and an onshore wind turbine needs three to four tonnes per megawatt. J.P. Morgan estimates that data centers alone will use about 475,000 tonnes in 2026.

The mines that exist are aging, and the new ones are in the Congo, Peru, Mongolia, and Russia. The large Western projects have been held up for years: Resolution in Arizona received its land only in 2026, Pebble in Alaska was vetoed in 2023, and Panama's Cobre Panama has been shut since November 2023. The Congo has become the story: Kamoa-Kakula and CMOC's mines pushed the country past Peru into second place, with 3.2 Mt in 2025.

4b. The Price Record

Date	LME price ($ a tonne)	Context
2003	About 1,800 (average)	Before China's boom
2008	About 8,900 (July peak); about 2,800 (December low)	The supercycle and the crash
February 2011	About 10,190	China's stimulus; the record for a decade
January 2016	About 4,300 (low)	The bust; mine closures
March 2022	About 10,800	Russia's invasion of Ukraine
2023	About 8,500 (average)	The lull; China's property slump
2025	Just under 10,000 (average); above 12,000 by year-end	Grasberg's mud rush; Kamoa-Kakula's flooding; the US tariff of 50% on semi-finished copper from August 1
January 29, 2026	14,527.50 (intraday)	Speculative buying in China; a weaker dollar
August 6, 2026	14,369.50	The Congo's concentrate order reported; LME stocks falling
September 10, 2026	14,875, the record	Expectations of a US tariff on refined copper
October 8, 2026	14,614.50	A strike at Centinela; Chinese buyers restocking after a holiday

LME cash or three-month prices; figures before 2025 are approximate.

Copper's 2026 records came from a combination the market had forecast for a decade and discounted. Mines were disrupted, as Kamoa-Kakula flooded in May 2025, El Teniente's tunnels collapsed in July, and Grasberg's mud rush followed in September, while Chinese smelters cut output as treatment charges reached zero and demand rose from grids, data centers, and defense.

American tariff policy split the world price: a 50% tariff on semi-finished copper took effect on August 1, 2025, and the administration studied a duty on refined copper of 15% from January 2027, rising to 30% in 2028. The threat drew metal into US warehouses, so that July 2026 imports exceeded 200,000 tonnes, a monthly record, and New York traded several hundred dollars a tonne above London that summer. As of September 10, 2026 the White House had made no final decision, weighing reshoring against the cost to manufacturers before the midterm elections.

Outside the United States the market tightened: LME stocks fell for 42 straight days to about 205,000 tonnes in mid-August, and the premium of spot copper over the three-month contract, called backwardation and a sign of physical scarcity, reached $434 a tonne, a five-year high.

4c. Is There a Copper Deficit?

The case for a deficit. Miners and most bank analysts see a market short of metal now and much shorter later. In June 2026 J.P. Morgan, UBS, and Morgan Stanley forecast 2026 deficits of roughly 330,000, 520,000, and 600,000 tonnes, pointing to disruptions at Grasberg, Kamoa-Kakula, and El Teniente and to mine output growing only about 1.6% in 2026. Over the longer run, the IEA's 2025 Outlook found that announced projects would leave supply about 30% short of demand by 2035.

The case for a balanced market. The International Copper Study Group (ICSG), whose members are producing and consuming governments, forecast in April 2026 a refined surplus of 96,000 tonnes in 2026 and 377,000 in 2027. That reversed its October 2025 forecast of a 150,000-tonne deficit, because demand was growing more slowly and more metal was coming from scrap. On this view the metal exists: US stocks

were estimated at well over 1 million tonnes in August 2026, drawn in by the tariff threat, and high prices are already pushing buyers toward aluminum and thinner cable.

The evidence. Both sides describe real data. Refined metal is plentiful in American warehouses and scarce elsewhere, where LME stocks fell and backwardation reached a five-year high, while concentrate, the mines' product, is scarce enough that smelters have agreed to process it for nothing. The IEA's 2026 Outlook says the long-run gap between demand and announced supply has narrowed but not closed.

The course's reading. The near-term balance is close and distorted by tariffs that moved metal rather than created it, but the long-run gap is real, because the mines needed for the 2030s are not being built at the rate the forecasts require. The price is high because the market outside the United States is tight now and the mine pipeline is thin later.

4d. The Congo's Order and the Mines in Question

On June 29, 2026 the Congo's government signed an order, reported on August 6, that bans exports of copper and cobalt concentrates, with one-year waivers possible in strategic circumstances, and sets a new tax on byproducts. The country had formally banned unprocessed concentrate exports for about a decade but routinely granted waivers, and the new order ends the routine ones, leaving only the strategic exception. Ivanhoe Mines said that Kamoa-Kakula's concentrate is now smelted inside the country, at its own smelter or at the Lualaba smelter in Kolwezi.

Three other mines frame the supply question. Grasberg in Indonesia, among the world's largest copper mines, restarted its block cave in 2026 after the mud rush that killed seven workers, and Freeport expects it near full capacity by the end of 2027. Cobre Panama, about 1.5% of world supply before it closed, has processed only stockpiled ore since May 2026, and on September 30 a Panamanian government commission recommended that any restart serve only to pay for an orderly closure.

Resolution Copper in Arizona, owned by Rio Tinto and BHP, received title to the Oak Flat land on March 16, 2026, after a federal appeals court refused to block the transfer, but litigation continues and production is years away. The company says the deposit could yield up to 40 billion pounds of copper over forty years, about 18 million tonnes.

Worked example — The Copper Deficit

Refined output was about 29 million tonnes in 2025, and if demand grows 2.5% a year, a little above the study group's near-term forecast and below the bulls', it reaches about 37 Mt by 2035. Output from existing mines falls about 2% a year without new investment, as grades decline and pits deplete, so today's 23 Mt of mined copper shrinks to about 19 Mt. Scrap supplies about 5 Mt now and perhaps 7 Mt by 2035, and the projects that are announced or probable, from Kamoa-Kakula's expansions to Oyu Tolgoi, Quebrada Blanca, Udokan, Reko Diq, and Resolution if it proceeds, add perhaps 6-8 Mt.

Supply then reaches about 32-34 Mt against 37 Mt of demand, a gap of 3-5 Mt, or about a tenth of the market. A gap of that size does not mean the metal runs out; it means the price rises until demand is cut, as aluminum replaces copper in wiring and grid projects are delayed, or until marginal mines are built. On the cost curve of Module 2 a new low-grade mine in Chile or Peru needs well above $10,000 a tonne to earn its capital, so the deficit is a price forecast, and copper above $14,000 in 2026 is the market's first installment.

Module 4 Key Points

Copper

• Chile mined 23% of the world's 23 Mt of copper in 2025; China refined 14 of 29 Mt, nearly half.

• LME copper set a record of $14,875 a tonne on September 10, 2026, on mine disruptions, smelter cuts, and tariff fears.

• The threat of a US duty on refined copper pulled record imports into American warehouses and tightened the market elsewhere.

• The study group forecasts small surpluses for 2026-27 and banks forecast deficits; the long-run gap in new mines is real.

• The Congo's 2026 order ends routine waivers for concentrate exports, pushing the smelting of its copper and cobalt into the country.

Module 4 Quiz

Check Your Understanding

1. Which country mined the most copper in 2025?

A) Peru
B) Chile, with 23%
C) The Congo, which passed Chile in 2025 on Kamoa-Kakula's growth
D) China, which mines nearly half the world's copper and refines even more

2. What did the International Copper Study Group forecast in April 2026?

A) A deficit of 600,000 tonnes
B) A small refined surplus in 2026 and 2027
C) A deficit of 150,000 tonnes in 2026, its third straight annual shortfall
D) A balanced market in 2026, then a 30% shortfall by 2027 as mines deplete

3. How did US tariff policy affect the copper market in 2026?

A) The threat of a duty on refined copper drew record imports into US warehouses and tightened supply elsewhere
B) It cut American imports of copper to zero
C) It pushed New York's price below London's
D) It had no effect, since refined copper is exempt

4. What does backwardation in the copper market signal?

A) That futures sit above spot because warehouses are full
B) That the LME has suspended trading after a disorderly session
C) Physical scarcity
D) That Chinese buyers are hedging against a weaker yuan

5. What did the Congo's June 2026 order do?

A) Nationalized Kamoa-Kakula
B) Banned all exports of copper
C) Raised the cobalt export quota to 200,000 tonnes a year so as to cut the price of hydroxide
D) Ended routine waivers for exports of copper and cobalt concentrate

Module 5 — Lithium

The Battery Metal and Its Cycle

Recommended Reading / Reference

Reference: USGS, *Mineral Commodity Summaries 2026* (lithium); Benchmark Mineral Intelligence, *Q3 2026 Lithium Price Review* (October 2, 2026); IEA, *Global Critical Minerals Outlook 2026*; company reports from Albemarle, SQM, Ganfeng, Pilbara Minerals, and Lithium Americas; Chile's National Lithium Strategy (2023); Zimbabwe's 2026 export rules

5a. Resources and Production

Country	Output, 2025 (t of lithium)	Share	Reserves (Mt of lithium)	Type	Note
Australia	92,000	32%	8.4	Hard rock (spodumene): Greenbushes, Pilgangoora, Wodgina	Concentrate shipped to China; mines idled in 2024-25 restarting in 2026
China	62,000	21%	4.6	Lepidolite in Jiangxi (high cost); brines in Qinghai and Tibet	The refining hub; CATL's Jianxiawo mine halted in 2025 and again in 2026
Chile	56,000	19%	9.2	Brine in the Atacama: SQM, Albemarle	The Codelco-SQM partnership from December 2025; water and indigenous claims
Zimbabwe	28,000	10%	0.5	Hard rock, mostly Chinese-owned (Huayou, Sinomine, Chengxin)	Exports suspended in February 2026, then allowed under quotas; a concentrate ban due in January 2027
Argentina	23,000	8%	4.4	Brine: Rio Tinto (Arcadium), Ganfeng, Posco, Eramet	A 2024 investment regime with tax and currency guarantees; 28 Mt of resources
Brazil, Mali, Canada	12,000; 9,400; 5,600	9% together	2.5 together	Hard rock: Brazil's Grota do Cirilo, Mali's Goulamina, Quebec	Mali's output rose more than tenfold in 2025
United States	Withheld	—	4.4	Brine at Silver Peak, Nevada; clay at Thacker Pass; Arkansas brines by direct extraction	Thacker Pass targeted for late 2027; US resources of 30 Mt are the world's largest
World	About 290,000, excluding the US	100%	37	Hard rock and brine, with direct extraction rising	About 150 Mt of identified resources

USGS, *Mineral Commodity Summaries 2026*. Output is in tonnes of lithium content; multiply by about 5.3 for lithium carbonate equivalent (LCE).

Lithium is not scarce: reserves of about 37 million tonnes would last more than a century at 2025's output, and identified resources are four times larger. Nor is its mining especially concentrated, since Australia digs about a third and China, Chile, Zimbabwe, and Argentina follow.

Its criticality lies in the chemistry, because most of the world's battery-grade lithium carbonate and hydroxide is made in China, which imports Australian and African concentrate and sells chemicals and cathode materials to the world. Its market is also the energy transition's most volatile: demand grew roughly tenfold in

a decade, supply arrives in large lumps years after it is ordered, and a small imbalance moves the price by multiples.

5b. The Cycle, Worked

Date	Lithium carbonate, battery grade	Context
2021	$11,700 (average)	The first electric-car wave
November 2022	About $80,000 in China (the peak)	Demand outran supply; the bubble
2022	$63,700 (average)	The year of the bubble
2023	$39,000 (average), falling all year	New supply, Chinese destocking, slower electric-car growth
2024	$11,800 (average)	The bust: mines idled, projects cancelled
2025	$9,000 (average); a low near $8,000 in mid-year	CATL's Jianxiawo mine halted in August; grid-storage demand rose
Mid-May 2026	Above 200,000 yuan a tonne on the Guangzhou futures exchange	The spike: storage demand, Zimbabwe's suspension, costlier acid
End of June 2026	About 161,000 yuan a tonne	The retreat begins
End of September 2026	127,750 yuan a tonne ($19,025), down 20.8% in the quarter	Australian mines restarting; China pausing approvals for new cell plants

Annual averages are the USGS's (real dollars); 2026 prices are ex-works China from Benchmark and the Guangzhou Futures Exchange.

Worked example — A Lithium Mine Through the Cycle

An Australian mine produces 300,000 tonnes a year of spodumene concentrate at 6% lithium oxide, enough for about 40,000 tonnes of LCE, at a cash cost of about $600 a tonne, and concentrate sells for roughly a tenth of the carbonate price. In late 2022, with concentrate near $8,000 a tonne, the mine earned about $2.2 billion a year on $180 million of costs, a margin that drew every junior miner in Western Australia and Zimbabwe into production and every Chinese converter into expansion.

In 2025, with concentrate near $800, the same mine earned about $60 million, while marginal mines with costs of $1,000 or more lost money and were idled, Western producers wrote down their assets, and China's lepidolite mines, the world's costliest, cut output. At the end of September 2026, with concentrate at $1,780, the mine earns about $350 million, and the idled mines are restarting.

The projects cancelled in 2024 are now two years further from production than they would have been, and that is the cycle's lesson: a rise in price from a low base changes nothing about supply for years, and everything about investment decisions that mature much later.

5c. Storage, Acid, and the Producers' Policies

The rebound of 2025-26 came from a source the 2022 forecasts barely included: grid batteries, which mostly use lithium iron phosphate (LFP) cells that need lithium and iron but no nickel or cobalt. Worldwide installations rose 54% in the first half of 2025 by Rho Motion's count, and US utility-scale battery capacity reached 43.6 gigawatts (GW) at the end of 2025 and nearly 52 GW by June 2026, according to the Energy Information Administration (EIA).

Costs rose as well: after the 2026 Hormuz shock, sulfuric acid went from about 3% to 11% of the cash cost of making lithium chemicals from hard rock, according to Benchmark.

The producers have adopted the tools of Module 12: Chile's 2023 National Lithium Strategy puts the state into new brine projects, and Codelco's partnership with SQM in the Atacama, NovaAndino Litio, began operating on December 29, 2025 and runs to 2060. Argentina went the other way in 2024, offering tax and currency guarantees that drew a dozen projects.

Zimbabwe suspended exports of lithium concentrate and all raw minerals on February 25, 2026, citing malpractice; it had shipped 1.13 Mt of concentrate in 2025. From April it allowed exports under quotas for producers that commit to build lithium sulfate plants, ahead of a ban on concentrate exports due in January 2027. In China, CATL's Jianxiawo mine restarted informally in July 2026, stopped again in August, and lost its environmental approval in September.

The American answer is Thacker Pass in Nevada, backed by a $2.23 billion Energy Department loan, a federal stake of 5% in Lithium Americas and 5% in the project taken in October 2025, and General Motors as partner and buyer; first production is targeted for late 2027. On August 3, 2026 the Defense Logistics Agency cancelled a tender to buy up to $300 million of lithium carbonate, about 16,000 tonnes, after two delays, a sign that the logic of a lithium stockpile is unsettled.

Module 5 Key Points

Lithium

• Lithium is not scarce: reserves of 37 Mt would last over a century; China's grip lies in chemical refining.

• Australia mined 32% of 2025's lithium, China 21%, Chile 19%, Zimbabwe 10%, and Argentina 8%.

• Carbonate fell from about $80,000 in 2022 to a $9,000 average in 2025, then ended September 2026 near $19,000.

• Grid storage drove the rebound, and acid rose to 11% of hard-rock refining costs after the Hormuz shock.

• Zimbabwe suspended concentrate exports in February 2026; the Pentagon's stockpiling agency cancelled a $300 million lithium purchase in August.

Module 5 Quiz

Check Your Understanding

1. Where does lithium's criticality lie, given that it is not scarce?

A) In its price alone
B) In Chile's brines
C) In the chemistry: most battery-grade carbonate and hydroxide is made in China
D) In mining, which China controls through its own deposits

2. How did battery-grade lithium carbonate move between late 2022 and September 2026?

A) It rose steadily
B) It held near $20,000 throughout
C) It fell from $80,000 to $40,000 and has held there since 2023 on long-term contracts
D) It collapsed to about $9,000 in 2025, then rebounded to about $19,000

3. In the worked example, what does the mine earn at September 2026's concentrate price?

A) About $350 million a year
B) About $60 million
C) About $2.2 billion a year, as in 2022
D) It loses money, since concentrate sells below cost

4. What drove the 2025-26 rebound in lithium demand?

A) Western electric-car sales doubling in both years
B) Grid batteries
C) Consumer electronics, led by new phones and laptops
D) Batteries for electric aircraft and drones

5. What did Zimbabwe do in 2026?

A) Nationalized its mines
B) Lifted its export tax
C) Joined a producers' cartel with Chile and Argentina to set a floor under the lithium price
D) Suspended concentrate exports, then allowed them under quotas

Module 6 — Nickel and Cobalt

The Two Metals One Country Each Controls

Recommended Reading / Reference

Reference: USGS, *Mineral Commodity Summaries 2026* (nickel and cobalt); the International Nickel Study Group; the Cobalt Institute's market reports; Indonesia's 2026 mining-quota decisions; the DRC's cobalt-quota decisions of 2025; Benchmark Mineral Intelligence, *Q3 2026 Cobalt Price Review* (September 30, 2026)

6a. Nickel: Indonesia's Two-Thirds

Country	Mined, 2025 (kt)	Share	Note
Indonesia	2,600	67%	Up from about a quarter in 2018; the 2020 ore-export ban built the industry; 2026 quota cut; a national mineral exchange planned by January 1, 2027
Philippines	270	7%	Ore shipped to China and Indonesia; Palawan's 50-year ban on new mining permits
Russia	200	5%	Norilsk, a maker of high-purity nickel and palladium
Canada	140	4%	Vale's and Glencore's operations at Sudbury
New Caledonia	140	4%	Recovering from the unrest of 2024
China	120	3%	The processor at home and, through its companies, in Indonesia
Australia	45	1%	Down from 98 kt in 2024; BHP suspended Nickel West in October 2024
World	3,900	100%	Stainless steel takes most; batteries a smaller, contested share

USGS, *Mineral Commodity Summaries 2026*. LME nickel averaged $16,812 a tonne in 2024 and $15,000 in 2025, and stood at $15,700 on October 9, 2026.

Indonesia did to nickel what the Organization of the Petroleum Exporting Countries (OPEC) never quite managed with oil: it banned exports of nickel ore in January 2020 and let Chinese companies, Tsingshan above all, build a processing industry on the islands of Sulawesi and Halmahera. The plants turn laterite ore into feed for stainless steel and, through high-pressure acid leaching, into battery-grade nickel at a cost no one else matches, and Indonesia's share of mined nickel rose from about a quarter in 2018 to 67% in 2025.

The glut ran for years: the International Nickel Study Group counted a surplus every year from 2022, prices fell from the March 2022 spike to about $15,000 a tonne in 2025, and Western mines closed, among them BHP's Nickel West in Australia.

Then Jakarta turned the tap: in February 2026 the energy ministry approved mining quotas of 260-270 million wet tonnes of ore for the year, against 379 million for 2025, through the RKAB, the annual work plan and budget each miner must have approved. LME nickel rose from just above $14,000 in mid-December 2025 to more than $17,000 by February 11, 2026, and on August 14 President Prabowo Subianto announced a national mineral exchange, due by January 1, 2027, to make Indonesia a 'price setter' for nickel.

The rally faded: nickel fell to a nine-month low in late September and stood at $15,700 on October 9, 2026, though the quota sits below the roughly 315 million tonnes of ore the smelters need to run at full rates. The Iran war raised the cost of the sulfur that high-pressure leaching consumes, more than 10 tonnes for each

tonne of nickel, so that sulfur rose from 26% to 42% of those plants' costs, and water shortages forced some smelters at the Morowali industrial park to cut output.

Nickel's demand picture cuts the other way, since stainless steel takes most of it and the battery share is contested as iron-phosphate cells, which use no nickel, take market share. Its criticality is more about Indonesia's control than about the energy transition's need.

6b. Cobalt: The Congo's Three-Quarters

Date	Event	Price
2018	The first electric-car spike	Metal about $95,000 a tonne at the peak
2022	The second spike	Metal about $80,000 at the peak
2023-24	Indonesian byproduct cobalt from nickel leaching floods the market; cobalt-free LFP cells take share	LME cash about $26,000 a tonne, $11.84 a pound (2024 average)
February 2025	The DRC suspends exports for four months to clear a glut, then extends the suspension	Metal near $10 a pound, about $22,000 a tonne
October 16, 2025	Quotas replace the suspension: 18,125 tonnes for the rest of 2025, then up to 96,600 tonnes a year for 2026 and 2027, including 9,600 for a strategic reserve	The US spot price for cathode, which carries a premium over the LME, averaged $21 a pound in 2025, against $16.77 in 2024
June 2026	Congolese hydroxide shipments to China exceed 10,000 tonnes (gross weight) for the month as quota exports flow	Prices still rising
Through August 2026	Refiners compete for scarce feed	Metal above $25 a pound, about $55,000 a tonne
Third quarter of 2026	A standoff between hydroxide buyers and sellers	Hydroxide down 31% to $17.25 a pound; metal down about 11% in September

USGS; Benchmark, *Q3 2026 Cobalt Price Review*; earlier peaks approximate. A price of $1 a pound equals about $2,205 a tonne.

The Democratic Republic of the Congo mined about 230,000 tonnes of cobalt in 2025, 73% of the world's unrounded total, and Indonesia, where cobalt comes out of the nickel-leaching plants, was second at 14%. Congolese cobalt is a byproduct of copper mines run by CMOC, Glencore, and others, and of an artisanal sector of informal diggers whose conditions made cobalt a byword for abuse in supply chains. China refines most of it and, through CMOC and Huayou, mines a growing share.

The 2025-26 sequence is this course's case study in producer power: facing a glut and a price near $10 a pound, Kinshasa suspended exports in February 2025 and then extended the suspension. In October the Strategic Minerals Market Regulation and Control Authority (ARECOMS) replaced it with quotas: 18,125 tonnes for the rest of 2025, then up to 96,600 tonnes a year for 2026 and 2027, with 9,600 tonnes of that held for a strategic reserve. The quota is well under half of the country's output.

Prices more than doubled, and metal held above $25 a pound through August 2026 before the squeeze eased. Hydroxide, the intermediate that refiners buy, fell 31% in the third quarter to $17.25 a pound as buyers and sellers held out against each other, and metal fell about 11% in September. Benchmark calls the pace at which the quotas are actually used a swing factor for prices.

The quota is administered scarcity in its purest form, and it has worked because the alternatives, Indonesian byproduct cobalt, Australian and Canadian mines, and recycling, cannot replace more than 100,000 tonnes in two years.

Worked example — The Cobalt Squeeze From Both Sides

A cathode maker in Korea needs 5,000 tonnes of cobalt a year for nickel-manganese-cobalt (NMC) cells, and early in 2025 it bought at about $22,000 a tonne of contained cobalt, or $110 million. With metal near $55,000 in mid-2026 the same cobalt costs $275 million, an extra $165 million a year, or about $3 per kilowatt-hour (kWh) on cells that sell for well under $100 per kWh: a cost increase of a few percent that the automaker absorbs or passes on.

For the Congo the arithmetic runs the other way, because the quota roughly halves export volume while the price more than doubled. Valued at metal prices, which overstate what the Congo is paid for hydroxide but serve for the comparison, 2024's output of 226,000 tonnes at early 2025's $22,000 a tonne was worth about $5.0 billion. The quota's 96,600 tonnes at $55,000 are worth about $5.3 billion. The state's share rises further, because the quota and the reserve capture margins that traders once took, and every producer in Module 12 has noticed that arithmetic.

For the battery industry the squeeze speeds what was already happening: lithium iron phosphate cells, with no cobalt, made up about half of the world's electric-car batteries and nearly all of its grid batteries by 2025, and high-nickel NMC uses about a third of the cobalt of 2018's chemistry. The Korean maker's response is to shift its mix rather than to find new cobalt, so the producer wins the decade and the material loses the century, the pattern of every mineral squeeze since 2010.

Module 6 Key Points

Nickel and Cobalt

• Indonesia mined 67% of the world's nickel in 2025, after its 2020 ban on ore exports drew in Chinese processing.

• Jakarta cut 2026 ore quotas to 260-270 million wet tonnes from 379 million, and plans a nickel exchange by 2027.

• The Congo mined 73% of the world's cobalt in 2025 and capped exports at 96,600 tonnes a year for 2026-27.

• Cobalt more than doubled under the quotas, then hydroxide fell 31% in the third quarter of 2026 in a buyers' standoff.

• The squeeze speeds the shift to cobalt-free LFP cells: the producer wins the decade, and the material loses the century.

Module 6 Quiz

Check Your Understanding

1. How did Indonesia come to mine two-thirds of the world's nickel?

A) It banned ore exports in 2020, and Chinese companies built the processing plants on its islands
B) It discovered new deposits on Sulawesi
C) It nationalized Vale's mines in 2019
D) It formed a cartel with the Philippines

2. What did Indonesia do to nickel supply in 2026?

A) Banned all nickel exports, including refined metal, for the full year
B) Raised its quotas to win back market share from the Philippines
C) Cut mining quotas
D) Sold its state mining company to Chinese investors to raise capital

3. What is the Congo's cobalt export quota for 2026 and 2027?

A) 10,000 tonnes
B) Up to 96,600 tonnes a year
C) 220,000 tonnes a year, its full output, with a tax on each shipment
D) A total ban on exports until 2028, to force refining at home

4. Why has the Congo's quota worked where a cartel might fail?

A) Demand is rising in every chemistry
B) The alternatives, from Indonesian byproduct to recycling, cannot replace 100,000 tonnes in two years
C) China agreed to enforce it
D) Cobalt has no substitute anywhere

5. In the worked example, what is the battery industry's response to the squeeze?

A) Shift the chemistry away from cobalt
B) Stockpile cobalt
C) Fund new cobalt mines in Australia and Canada to replace Congolese supply
D) Pay whatever the Congo asks for as long as the quota lasts

Module 7 — Graphite, Manganese, and the Battery-Chain Minerals

The Anode and the Cathode's Other Inputs

Recommended Reading / Reference

Reference: USGS, *Mineral Commodity Summaries 2026* (graphite and manganese); China's Ministry of Commerce announcements of October 2023, October 2025, and November 2025; the US International Trade Commission's determination on active anode material from China (March 12, 2026); Benchmark Mineral Intelligence's anode and cathode reports; SNE Research's battery installation data

Mineral	Role in the battery	Output (2025)	Processing	Chinese controls	Western projects
Graphite, natural	The anode: about 1 kg per kWh, the largest mineral input by weight	1.8 Mt mined; China 1.4 Mt, then Madagascar, Tanzania, Brazil, Mozambique	China makes more than 90% of anode material	Licensing since December 2023	Syrah's Vidalia (Louisiana), Westwater (Alabama), Nouveau Monde (Quebec)
Graphite, synthetic	The anode: baked from petroleum needle coke at about 3,000°C; most anode use	Not tracked by the USGS	China dominant; energy-intensive	The October 2025 controls on artificial graphite anode material, suspended under the truce until January 10, 2027	Novonix (Tennessee), Vianode (Norway), Posco Future M (Korea)
Silicon, an anode additive	Silicon-carbon anodes raise energy density	Small	China leads in silicon and polysilicon	—	Sila Nanotechnologies (a $1.4 billion Pentagon commitment, August 2026), Group14
Manganese, high-purity sulfate	Nickel-rich (NMC) cathodes and lithium manganese iron phosphate (LMFP)	Ore led by South Africa, Gabon, Australia	China about 95% of the sulfate	Not controlled	Element 25 (Louisiana), Euro Manganese (Czechia)
Phosphate, purified phosphoric acid	Lithium iron phosphate (LFP) cathodes	Rock led by China, Morocco, the US	China makes most battery-grade acid	Not controlled	Morocco's OCP; American fertilizer producers exploring
Fluorspar, for the electrolyte salt lithium hexafluoro phosphate (LiPF6)	The electrolyte	China and Mexico lead	China makes most of the salt	—	Few
Copper and aluminum foil	Current collectors	—	China makes most battery copper foil	—	Korean and Japanese foil makers

USGS, *Mineral Commodity Summaries 2026*; Benchmark; company disclosures. NMC = nickel-manganese-cobalt.

7a. Graphite: The Anode and the Failed Duty Case

Every lithium-ion battery's anode is graphite, about a kilogram per kilowatt-hour and more than any other mineral in the cell by weight, and China makes more than 90% of the world's anode material. It uses natural graphite that it mines or imports from Africa and, increasingly, synthetic graphite baked from petroleum coke. China mined about 1.4 of the world's 1.8 Mt of natural graphite in 2025, by the USGS's estimate, and its exports of spherical graphite, the anode-grade form, rose 29% in the first nine months of the year.

China put graphite under export licensing in December 2023 and in October 2025 extended the controls to artificial graphite anode material and the equipment to make it. That expansion was suspended, with the rare-earth controls, under the trade truce of October 30, 2025. The truce was due to end on November 10, 2026 and was extended in September 2026 to January 10, 2027, the date every battery and automotive purchasing office is now watching.

American producers tried trade law. They petitioned in December 2024 for duties on Chinese active anode material, and on February 11, 2026 the Commerce Department set final rates of 93.5% in antidumping duties and about 67% in countervailing duties against subsidies, about 160% combined. On March 12, 2026 the International Trade Commission (ITC) found that the imports had not injured or threatened the domestic industry, so no duties took effect.

The Western response is a handful of plants: Syrah's Vidalia plant in Louisiana, the first integrated natural-graphite anode plant outside China, running on Mozambican graphite; Novonix in Tennessee, making synthetic graphite; and Westwater's Alabama project, which won $25 million from the Export-Import Bank (EXIM) in August 2026. The same month the Pentagon committed $1.4 billion to Sila Nanotechnologies for silicon-carbon anodes and a cell plant. Together they meet a small fraction of what American cell plants will need, and Chinese material at about half the Western cost sets the price.

7b. The Cathode's Other Inputs

The cathode chemistry decides which minerals matter. Nickel-manganese-cobalt (NMC), the chemistry of most Western electric cars, needs nickel, cobalt, manganese sulfate, and lithium hydroxide, while lithium iron phosphate (LFP), the chemistry of most Chinese cars and nearly all grid storage, needs lithium carbonate, iron, and purified phosphoric acid and no nickel, cobalt, or manganese. A newer variant, lithium manganese iron phosphate (LMFP), adds manganese to raise energy density.

The shift from NMC to LFP is the largest single change in the transition's mineral demand. It removes cobalt and nickel from the fastest-growing segment, raises lithium carbonate's importance relative to hydroxide, and, because LFP's patents and plants were Chinese, moves the cathode industry to China more completely than NMC ever did.

Manganese and phosphate are not scarce: South Africa, Gabon, and Australia mine manganese, and Morocco holds about 70% of the world's phosphate rock reserves. Their battery-grade processing is Chinese, though, about 95% for high-purity manganese sulfate, which is the pattern of every row in the table. Both also depend on sulfuric acid, so the 2026 sulfur shock raised their costs too.

7c. The Chain's Arithmetic

A 75-kWh electric-car battery contains about 8 kilograms of lithium and 50-75 kilograms of graphite. An NMC pack adds 35-55 kilograms of nickel, 5-10 of cobalt, and some manganese, while an LFP pack adds about 45 kilograms of iron and 40 of phosphate, and either holds about 20 kilograms of copper in foil and wiring and 25 of aluminum.

SNE Research counted 1,187 gigawatt-hours (GWh) of electric-car batteries installed worldwide in 2025, and grid batteries add a fast-growing share on top. The materials in those packs make a market worth tens of billions of dollars a year that did not exist at a tenth of its size in 2015. It runs mostly through Chinese plants at every step, and it is now contested at once by American sourcing rules, China's November deadlines, and the Congo's and Indonesia's quotas.

Module 7 Key Points

Graphite, Manganese, and the Battery-Chain Minerals

• Graphite is the battery's largest mineral input by weight, about 1 kg per kWh, and China makes over 90% of anode material.

• China's October 2025 controls on synthetic graphite anodes are suspended only until January 10, 2027, under an extended truce.

• Commerce set duties of about 160% on Chinese anode material, but the ITC found no injury in March 2026, so none applied.

• The shift from NMC to LFP removes nickel and cobalt from the fastest-growing segment but moves cathodes further into China.

• Manganese and phosphate are abundant, yet China makes about 95% of the battery-grade manganese sulfate.

Module 7 Quiz

Check Your Understanding

1. What is the largest mineral input to a lithium-ion battery by weight?

A) Lithium, dissolved in the electrolyte and bound in the cathode
B) Cobalt, in the cathode's oxide layer of nickel-rich cells
C) Graphite
D) Nickel, in the cathode of every chemistry on the market

2. What happened to the American duty case against Chinese anode material in 2026?

A) Duties of 160% took effect
B) China agreed to a price floor
C) Commerce found no dumping, so the petition was withdrawn before the trade commission voted
D) The trade commission found no injury, so no duties applied

3. Why is the shift from NMC to LFP the largest change in the transition's mineral demand?

A) NMC is banned in China
B) It removes nickel and cobalt from the fastest-growing segment
C) LFP needs more cobalt per cell than NMC does
D) LFP cathodes require rare earths, which ties every battery to the magnet chain

4. Until when does the truce suspend China's October 2025 controls on synthetic graphite anodes?

A) November 10, 2026, as first agreed in Busan
B) November 27, 2026, with the minor metals
C) January 10, 2027, after the truce was extended in September 2026
D) Indefinitely, since the controls were repealed

5. Why are manganese and phosphate battery-chain risks, though both are abundant?

A) Both are mined only in China
B) Morocco restricts phosphate exports by quota, and South Africa bans manganese exports
C) They go into steel and fertilizer, which leaves too little for batteries
D) Their battery-grade processing is Chinese

Module 8 — Rare Earths and China's Export Weapon

The Seventeen Elements and the Confrontation Over Them

Recommended Reading / Reference

Book: Julie Michelle Klinger, *Rare Earth Frontiers: From Terrestrial Subsoils to Lunar Landscapes* (2017)

Reference: USGS, *Mineral Commodity Summaries 2026* (rare earths); IEA, *Global Critical Minerals Outlook 2026*; China's Ministry of Commerce announcements of April 4 and October 9, 2025 and the November 2025 suspensions; Benchmark Mineral Intelligence, *Q3 2026 Rare Earths Price Review* (September 25, 2026); the World Trade Organization's 2014 ruling on China's export restrictions; MP Materials' and Lynas's 2026 results

8a. The Elements and the Chain

Element	Use	Price	Supply	Note
Neodymium and praseodymium (NdPr)	The magnet workhorse: neodymium-iron-boron magnets in electric-car motors, wind turbines, robots, drones, and phones	China: 729,500 yuan a tonne ($108.7 a kilogram) in September 2026. Outside China: $106.5, below $110, the level of the Pentagon's floor. China's 2025 average was about $69	China: 69% of mining, 85% of refining	The light rare earths, and the volume market
Dysprosium and terbium	Added to magnets so they keep working hot: motors, missiles, jet engines	Dysprosium $3,500 a kilogram in Europe, about 16 times China's price; terbium oxide $6,745 a kilogram outside China (September 2026)	China nearly all separation; ore from Chinese and Burmese ionic clays; Lynas the main outside source since 2025	The heavy rare earths; licensed since April 2025
Samarium	Samarium-cobalt magnets for high heat, in missiles and aircraft	Rising	China nearly all	Licensed since April 2025
Yttrium, gadolinium, lutetium, scandium	Lasers, contrast agents for magnetic resonance imaging (MRI), coatings, alloys, radar	Yttrium outside China about 196 times China's price (September 2026)	China nearly all	Licensed since April 2025
Europium, holmium, erbium, thulium, ytterbium	Phosphors, lasers, fiber-optic amplifiers	Buyers report trouble exporting erbium and ytterbium	China nearly all	Added in October 2025; suspended
Lanthanum and cerium	Catalysts, polishing, glass, nickel-metal-hydride batteries	About $1-2 a kilogram in China (2025)	Abundant	The cheap ones; a byproduct surplus

Benchmark, *Q3 2026 Rare Earths Price Review*; USGS, *Mineral Commodity Summaries 2026*. Prices are for oxides; NdPr outside China is the delivered price, including cost, insurance, and freight (CIF), in North America and Europe.

The rare earths are seventeen metals that are not rare, since cerium is about as common as copper, but that are hard to separate from one another and from the radioactive thorium that accompanies them, and that separation chemistry is what China mastered and the West abandoned. Four matter most. Neodymium and praseodymium make the permanent magnets in electric-car motors, wind turbines, robots, drones, and

hard drives, and dysprosium and terbium, the heavy rare earths, are added so those magnets keep working when hot, in a missile's fin actuator, a jet engine, or a car's motor.

China mined 270,000 of the world's 390,000 tonnes of rare-earth oxide in 2025, at Bayan Obo in Inner Mongolia and in the ionic clays of the south, and it imports Myanmar's ore as well. It refined 85% of the world's rare earths in 2025, down from more than 90% in 2023, and makes about 94% of sintered magnets. The IEA estimates that if China's October 2025 rules were fully enacted, $6.5 trillion a year of production outside China could be at risk, though rare earths are less than 1% of a vehicle's value.

8b. The 2010 Lesson

The confrontation has a precedent. In September 2010, after Japan detained the captain of a Chinese fishing trawler near the disputed Senkaku Islands, China halted rare-earth shipments to Japan for weeks, at a time when it supplied about 97% of the world's rare earths, and prices rose severalfold within a year.

Japan drew the lesson. Its state agency, the Japan Organization for Metals and Energy Security (JOGMEC), invested in Lynas's Australian mine and Malaysian plant, which made Lynas the first large producer outside China, and Japanese companies built stockpiles and learned to use fewer heavy rare earths. The United States, the European Union, and Japan won a World Trade Organization (WTO) case against China's export quotas in 2014, and China dropped the quotas in 2015.

The West mostly did not draw it. Mountain Pass reopened under Molycorp, which went bankrupt in 2015, and MP Materials bought the mine in 2017 and shipped most of its concentrate to China for separation until April 2025. A decade of warning was spent on other things.

8c. The 2025-26 Confrontation

Date	Event	Effect
April 4, 2025	Two days after the US tariffs of April 2, China requires licenses for exports of seven medium and heavy rare earths (samarium, gadolinium, terbium, dysprosium, lutetium, scandium, yttrium) and the magnets containing them	Licenses stall; within weeks Ford idles its Chicago plant and Suzuki halts a model; European suppliers ration magnets; defense contractors report shortages
May-June 2025	Talks in Geneva and London; China agrees to issue licenses	Flows partly resume, slowly and selectively
July 2025	The Pentagon's deal with MP Materials (Module 13)	A price floor, an equity stake, and a guaranteed buyer
October 9, 2025	China extends controls to five more elements, to processing and magnet technology, and to foreign products containing Chinese rare earths worth 0.1% or more of their value	The escalation that produced the truce
October 30, 2025	Presidents Trump and Xi meet in Busan: China suspends the October measures for a year; the US suspends new port fees and its rule extending export controls to affiliates	The reprieve, to November 10, 2026
November 2025	The suspension is formalized; general licenses go to selected exporters; the April 2025 controls stay in force	Some buyers supplied; heavy rare earths still scarce
January 2026	China bans exports of dual-use items, rare earths among them, to Japanese military users	Japan's channel tightens
May 14-15, 2026	President Trump visits Beijing; no rare-earth agreement is confirmed	Exports of yttrium, dysprosium, and terbium remain about half their former level

Date	Event	Effect
June 9, 2026	China rejects an American request to resume rare-earth sales to Japan	The licenses as diplomacy
Third quarter of 2026	Dysprosium outside China reaches about 16 times the Chinese price, and NdPr outside China falls below $110, the level of the Pentagon's floor	A market split in two
September 24, 2026	As President Xi arrives in Washington, the two governments extend the truce by two months; China's Ministry of Commerce confirms it on September 28	The suspension now runs to January 10, 2027
January 10, 2027	The extended suspension expires	Another extension, selective renewal, or reimposition

Ministry of Commerce announcements; USGS; Benchmark; press reports.

On April 4, 2025, two days after the American tariffs announced on April 2, China placed seven rare earths and the magnets containing them under export licensing. Within weeks Ford had idled its Chicago assembly plant, Suzuki had stopped production of a model, European parts suppliers were rationing magnets, and American defense contractors were reporting shortages. It was the first time a Chinese mineral control had halted Western production lines, and it made rare earths the decisive card in the tariff war.

The truces of May and June restored flows slowly and selectively, and China's October 9 expansion, with controls on technology, on magnets, and on products made anywhere with Chinese rare earths, produced the October 30 truce that suspended it for a year. In September 2026 the truce was extended to January 10, 2027. Throughout, the suspension has worked as an instrument of diplomacy rather than a return to the market: general licenses ran for some buyers, while Japan's channel was cut for military users in January 2026 and China refused an American request in June to restore it.

Prices show a market split in two. NdPr outside China, which carried a premium in 2025, fell more than 13% in August 2026, to below $110 a kilogram, the level of the Pentagon's floor, while dysprosium in Europe reached about 16 times the Chinese price and yttrium about 196 times. The light rare earths are being diversified, and the heavy ones are not.

8d. The Alternatives and the Honest Timeline

Project	Country	Status (October 2026)	Scale
MP Materials: Mountain Pass, California; Independence and a larger magnet plant in Texas	US	NdPr output of 840 tonnes in the second quarter of 2026, with more than 1,000 expected in the third; magnet production since December 2025; first commercial magnets from the larger plant due in late 2026; a dysprosium-terbium circuit being commissioned	About 3,400 tonnes of NdPr a year at the second quarter's rate; 10,000 tonnes of magnets planned
Lynas: Mt Weld, Australia; Kuantan, Malaysia; Seadrift, Texas	Australia, Malaysia, US	A record fiscal 2026; heavy rare earths separated in Malaysia since May 2025; the Malaysian license renewed for ten years; the Texas plant in doubt since 2025	7,260 tonnes of NdPr in the year to June 2026
Iluka: Eneabba refinery	Australia	Under construction with a government loan of A$1.65 billion	Light and heavy oxides from 2027
USA Rare Earth: Stillwater, Oklahoma; Round Top, Texas	US	Definitive agreements with the Commerce Department for up to $1.6 billion (June 3, 2026)	Magnets planned to 10,000 tonnes a year; Round Top targeted for 2028

Project	Country	Status (October 2026)	Scale
Magnet start-ups: Vulcan Elements, eVAC, Noveon, Niron	US	Plants ramping; Niron's iron-nitride magnets use no rare earths ($150 million, August 2026)	Small
Solvay (France); Neo Performance (Estonia); Serra Verde (Brazil)	Europe; Brazil	Separation restarted at La Rochelle (2025); a magnet plant opened at Narva (2025); ionic-clay concentrate rich in heavy elements	Small
Recycling: Noveon, HyProMag, Cyclic	US, UK	Magnet-to-magnet recycling	Hundreds of tonnes

Company results and announcements, 2026; the IEA's projections are in the text.

The alternatives are real and small. MP Materials, with the Pentagon as shareholder and price guarantor, produced 840 tonnes of NdPr oxide in the second quarter of 2026 and began making magnets in Texas in December 2025. Lynas produced 7,260 tonnes of NdPr in its fiscal year to June 2026 and is the main source of separated heavy rare earths outside China, while Iluka, USA Rare Earth, and the magnet start-ups add capacity through 2028.

The IEA's projection gives the honest timeline. China's share of refining falls from 85% in 2025 to about 70% by 2035 if every planned plant is built, and even then planned refining capacity reaches only about two-thirds of expected mine output and planned magnet production only about a third. The light rare earths are being diversified by the end of the decade, the heavies and the magnets remain largely Chinese into the 2030s, and the truce's new end on January 10, 2027 will find the West still dependent for the elements its weapons need most.

Module 8 Key Points

Rare Earths and China's Export Weapon

• China mined 69% of rare earths in 2025, refined 85%, and makes about 94% of sintered magnets.

• China's 2010 cutoff of Japan was the warning; Japan answered by financing Lynas, while the West mostly waited.

• April 2025's licensing of seven rare earths halted Western auto lines within weeks; the October 2025 expansion is suspended until January 10, 2027.

• Prices split: NdPr outside China fell below $110 in August 2026, while dysprosium reached 16 times China's price.

• The IEA sees China's refining share falling only to 70% by 2035; the heavy rare earths stay Chinese into the 2030s.

Module 8 Quiz

Check Your Understanding

1. Why are rare earths critical if they are not rare?

A) They are hard to separate
B) They are radioactive and cannot be shipped by sea or air without special permits
C) They are found only in Chinese and Burmese deposits
D) They cost more per kilogram than gold, which deters stockpiling

2. What did Japan do after China's 2010 rare-earth cutoff?

A) Financed Lynas through its state agency, JOGMEC
B) Banned Chinese imports
C) Opened its own mines
D) Bought Mountain Pass in California and restarted its separation plant with American partners

3. What happened after China's April 4, 2025 licensing of seven rare earths?

A) Prices fell
B) Western plants were unaffected
C) The US banned Chinese magnets in response
D) Within weeks Ford idled a plant, Suzuki stopped a model, and defense contractors reported shortages

4. What happened to NdPr prices outside China in the third quarter of 2026?

A) They rose to 16 times the Chinese price, as dysprosium did
B) They fell below the $110 floor
C) They were fixed by the Pentagon at $110 for every buyer in the West
D) They doubled as China ended general licenses for American buyers

5. What does the IEA project for China's share of rare-earth refining?

A) Below 20% by 2030
B) Over 95% through 2035, as planned Western plants are cancelled
C) About 70% by 2035, from 85%
D) It holds at 85%, since no plants are planned outside China and Malaysia

Module 9 — The Strategic Minor Metals

The Metals With No Substitutes and One Supplier

Recommended Reading / Reference

Reference: USGS, *Mineral Commodity Summaries 2026* (gallium, germanium, antimony, tungsten, scandium, silver, tin); China's Ministry of Commerce announcements of 2023-25; the Bureau of Industry and Security's August 2026 restriction on exports of recoverable critical minerals; S&P Global's tungsten market report (August 2026); the Congressional Research Service on the National Defense Stockpile

Metal	Uses	China's share	Control status (October 2026)	Price	Alternatives
Gallium	Gallium-nitride and gallium-arsenide chips for radar, 5G networks, power electronics, and light-emitting diodes (LEDs); a byproduct of alumina refining	Nearly all of about 900 tonnes of primary output	Licensed since August 2023; the December 2024 ban on exports to the US lifted for a year in November 2025, until November 27, 2026	US imports averaged $580 a kilogram in 2025, up about 30%	Rio Tinto's Quebec pilot; Japanese recovery; recycling
Germanium	Infrared optics for night vision, thermal imaging, and missile seekers; fiber optics; satellite solar cells; a byproduct of zinc	Most refining	Licensed since August 2023; the US ban suspended until November 27, 2026	Up sharply since 2024	Teck (Red Dog, Alaska), Umicore (Belgium), 5N Plus (Utah, Pentagon-funded)
Antimony	Flame retardants, ammunition primers, lead-acid batteries, solar glass	About half of mining, more of refining	Licensed since September 2024; the US ban suspended until November 27, 2026	Several times its 2023 level at the 2025 peak	Perpetua's Stibnite mine (Idaho, targeted for 2028); Tajikistan; Australia
Tungsten	Cutting tools, armor-piercing munitions, drilling, electronics	79% of 85,000 tonnes mined; about 85% of APT	Licensed since February 2025; the US restricted its own scrap exports from August 2026	APT $675 per mtu in 2025; about $3,245 in the second quarter of 2026	Almonty (Sangdong, Korea, from July 2026); Vietnam's Nui Phao; Kazakhstan; Spain and Portugal
Scandium	Aluminum-scandium alloys for aircraft and missiles; fuel cells	Most of a market of about 60 tonnes a year	Licensed since April 2025, as one of the seven rare earths	High and opaque	NioCorp (Nebraska, planned for 2028); Sunrise Energy Metals ($400 million, August 2026); Rio Tinto (Quebec)
Silver	Electronics, solar cells, jewelry, investment	A large refiner	Exports licensed for 2026-27, to 44 approved companies	Records in 2025-26	Mexico, Peru; on the US critical list since November 2025

Metal	Uses	China's share	Control status (October 2026)	Price	Alternatives
Tin	Solder in every circuit board, tinplate, chemicals	The largest smelter; ore from Myanmar, Indonesia, the DRC	Not controlled; Myanmar's Wa State mine disrupted and Indonesia's crackdowns on illegal mining	About $51,400 a tonne on October 8, 2026, up about 39% in a year (LME-based, via Trading Economics)	Alphamin (the DRC), Minsur (Peru)
Indium, bismuth, tellurium, molybdenum	Displays and solar (indium), pharmaceuticals and alloys (bismuth), solar (tellurium), steel alloys (molybdenum)	Leading in each	Licensed since February 2025	Higher outside China	Korea, Canada, the US (tellurium from copper refining)

USGS, *Mineral Commodity Summaries 2026*; Fastmarkets; S&P Global; company and government announcements. APT = ammonium paratungstate; mtu = metric tonne unit.

9a. Why They Matter More Than Their Size

The strategic minor metals are produced in hundreds or thousands of tonnes a year, against copper's tens of millions, yet a modern military and electronics industry cannot do without them. Gallium nitride sits in radars, germanium in night-vision scopes and infrared missile seekers, antimony in primers and armor-piercing rounds, tungsten in penetrators and cutting tools, scandium in lightweight alloys, and tin in every solder joint.

Their economics are the source of the problem. Most are byproducts, gallium of alumina refining, germanium and indium of zinc, and tellurium of copper, so their supply follows the host metal's rather than their own price. China, which refines most of the world's alumina and zinc, recovers them as a matter of industrial policy, while Western smelters, lacking the volume and the subsidy, often let them go to waste. The result is Chinese shares from about half to nearly all in metals whose markets are worth tens to hundreds of millions of dollars a year and whose absence would idle industries worth trillions.

9b. The Control Calendar

China's minor-metal controls preceded the rare-earth ones and mapped the strategy. Gallium and germanium came under licensing in August 2023, after the American controls on chip exports, and antimony followed in September 2024. In December 2024, after the chip controls widened, China banned exports of gallium, germanium, and antimony to the United States outright, and in February 2025, after the first tariffs, it licensed tungsten, indium, bismuth, tellurium, and molybdenum.

Each step was timed to an American action and aimed at a metal in which China's share is decisive and the West's stockpile thin. In November 2025, under the truce, China lifted the American ban for a year, until November 27, 2026, though the licensing remains. The announcements of September 2026 that extended the truce to January 10, 2027 did not mention that date.

The United States has answered in kind. Using Defense Production Act authority delegated in July 2026, the Commerce Department's Bureau of Industry and Security (BIS) restricted exports of tungsten waste and scrap and of black mass, the shredded material from recycled lithium-ion batteries, for one year from late August. Suppliers must sell at home unless they win an exemption, so the trade in these metals has become a mutual embargo managed by exception.

9c. Tungsten's Fivefold Rise

Tungsten shows what controls do to a small market. The price of ammonium paratungstate (APT), the traded intermediate, averaged $331 per metric tonne unit in 2024 and $675 in 2025, according to the USGS. It then rose more than fourfold between January and July 2026, averaging about $3,245 in the second quarter, nearly five times the 2025 average. China mines about 79% of the world's tungsten and makes about 85% of its APT, and its production quotas and export licensing tightened supply just as defense demand rose.

Supply outside China is answering slowly. Almonty began processing at Sangdong in South Korea in July 2026, with about 90% of the first phase committed to Global Tungsten & Powders, an American maker, and from January 1, 2027 American defense rules bar contractors from buying Chinese tungsten powder and heavy alloys. S&P Global still sees a gap outside China of about 21,000 tonnes of tungsten trioxide in 2026, narrowing to about 12,000 by 2028.

9d. The Defense Exposure and the Stockpile

The exposure is calculable. An F-35 fighter contains about 417 kilograms of rare-earth materials and a Virginia-class submarine about 4.2 tonnes, by figures the Congressional Research Service has cited, and missiles carry gallium, germanium, antimony, and tungsten in parts no domestic supplier makes. The shortage reports of the defense contractors in 2025 were the first public admission that the arsenal's supply chain runs through the adversary it is built to deter.

The National Defense Stockpile, run by the Defense Logistics Agency (DLA), was left a fraction of its Cold War size by decades of sales, and the July 2025 budget law added $2 billion to rebuild it. A July 2026 executive order made it harder for defense contractors to win waivers to buy from China and other prohibited suppliers, and in August Lockheed Martin was negotiating for scandium from NioCorp's planned Nebraska mine and for germanium from Teck and 5N Plus.

The same week the DLA cancelled its lithium tender, a reminder that the stockpile buys what the military needs rather than what the civilian economy does.

Module 9 Key Points

The Strategic Minor Metals

• The minor metals are made in hundreds or thousands of tonnes, yet radars, night-vision scopes, and ammunition cannot do without them.

• Most are byproducts of alumina, zinc, or copper refining, which China recovers as policy and Western smelters often waste.

• China's controls ran from gallium in 2023 to tungsten in 2025; its ban on exports to the US is suspended until November 27, 2026.

• Tungsten's APT price rose from $675 per mtu in 2025 to about $3,245 in the second quarter of 2026.

• An F-35 holds about 417 kg of rare-earth materials; Washington now restricts its own scrap exports and tightens defense sourcing.

Module 9 Quiz

Check Your Understanding

1. Why does China dominate the minor metals despite their tiny markets?

A) It holds the only deposits
B) A 2001 trade ruling assigned it the market
C) Western countries banned mining them
D) Most are byproducts of alumina and zinc refining, which China recovers as policy

2. What pattern does China's control calendar show?

A) Each control was timed to an American action
B) Random timing
C) Controls on rare earths only
D) Every control lapsed within a year because Chinese exporters lobbied against it

3. What did the United States restrict in August 2026?

A) Imports of Chinese gallium and germanium for chipmakers
B) Sales from the National Defense Stockpile to allied governments
C) Exports of tungsten scrap and black mass
D) All exports of refined copper, to build domestic supply for the grid

4. How did the price of ammonium paratungstate change from 2025 to mid-2026?

A) It halved
B) It rose about fivefold
C) It held steady near $675 per metric tonne unit
D) It fell as China lifted its tungsten export licensing under the truce

5. What does an F-35 contain, by the figure the module cites?

A) About 4 tonnes of tungsten penetrators and armor
B) About 50 kilograms of gallium in its radar modules
C) About 417 kg of rare earths
D) Only domestic metals, since its parts are made in the US

Module 10 — The Bulk Metals: Iron Ore, Bauxite, and Aluminum

The Largest-Volume Mined Commodities

Recommended Reading / Reference

Reference: USGS, *Mineral Commodity Summaries 2026* (iron ore, bauxite and alumina, aluminum); Rio Tinto's Simandou disclosures (2025-26); the World Steel Association; the International Aluminium Institute; Emirates Global Aluminium's and Aluminium Bahrain's statements on the strikes of March 28, 2026

Commodity	Output (2025)	Leading producers	Price	2025-26
Iron ore	2.6 billion tonnes of usable ore	Australia 980 Mt (38%), Brazil 420 Mt, India 310 Mt, China 290 Mt of low-grade ore	$90.68 a tonne for 62% iron delivered to China (October 9, 2026), down 14% in a year	Simandou's first ore in November 2025; China's steel demand falling and its steel exports provoking tariffs
Bauxite	440 Mt	Guinea 150 Mt (34%), Australia 97 Mt, China 87 Mt	—	Guinea revoked a license held by a subsidiary of Emirates Global Aluminium (EGA) in August 2025 and gave the concession to a state-backed company
Alumina	150 Mt	China 93 Mt (62%), Australia 17 Mt, Brazil 11 Mt	—	Indonesia's first new refinery since its 2023 bauxite export ban shipped in April 2025
Aluminum	74 Mt	China 45 Mt (61%), India 4.2 Mt, Russia 3.9 Mt, Canada 3.3 Mt, the United Arab Emirates 2.7 Mt, Bahrain 1.6 Mt	LME cash $3,134 a tonne (October 6, 2026), after about $3,665 in mid-April, a four-year high	China at its own 45 Mt cap; Iranian strikes on two Gulf smelters on March 28, 2026; a US tariff of 50% since June 2025

USGS, *Mineral Commodity Summaries 2026* (estimates for 2025); LME; the benchmark iron-ore price via Trading Economics.

10a. Iron Ore: The Triangle and Simandou

Iron ore is the largest mined commodity by volume, about 2.6 billion tonnes of usable ore in 2025, and most of the seaborne trade moves from Australia's Pilbara and Brazil's Carajás to China, which makes more than half of the world's steel. It shows what a bulk commodity's geopolitics look like: a triangle of two exporters and one buyer whose demand has peaked. China's steel demand has fallen with its property slump, its steel exports have provoked tariffs around the world, and the ore price stood at $90.68 a tonne on October 9, 2026, down 14% in a year.

Into that market came Simandou, the mountain of high-grade ore in southeastern Guinea that is the largest undeveloped deposit on earth. Found in the 1990s, it passed through Rio Tinto's hands, a corruption scandal over a license held by BSG Resources, a deal with Vale, Chinese consortia, and a coup in Guinea in 2021. A consortium of Rio Tinto, Chinese state companies, and the Singapore-based Winning group then

built a railway of more than 600 kilometers and a deepwater port, and shipped the first ore in November 2025.

Guinea shipped 5.7 Mt of iron ore through June 9, 2026, all of it to China, against about 375,000 tonnes in all of 2025, and analysts expect about 15 Mt for the year. At full capacity of 120 Mt a year Simandou's two mines would supply about 7% of seaborne ore, at grades near 65% iron that need less coal per tonne of steel. Financed and largely owned by its buyer, it is China's answer to the Australian-Brazilian duopoly, and the lesson of its thirty years is that the buyer with capital and patience gets the mountain.

10b. Bauxite and Aluminum

Aluminum is the second metal of the electric economy, in transmission lines, car bodies, solar frames, and wherever its price makes it a substitute for copper. Its chain runs from bauxite, where Guinea is now the largest producer with about a third of world output, to alumina, 62% of it Chinese, to smelting, the most energy-intensive step at about 14,000 kWh a tonne, which is why smelters follow cheap power to Iceland, the Gulf, Canada, and Chinese coal.

China capped its own smelting at 45 Mt in 2017 and reached the cap in 2025, with 61% of the world's 74 Mt. Guinea, which supplies most of China's imported bauxite, revoked dozens of mining licenses in 2025, among them the bauxite concession of EGA's local subsidiary after a dispute over building a refinery.

Then the war reached the smelters. The Gulf makes about 9% of the world's primary aluminum, and on March 28, 2026 Iranian missiles and drones hit EGA's Al Taweelah smelter in Abu Dhabi and the smelter of Aluminium Bahrain (Alba). Qatar's Qatalum smelter had already shut on March 3 for lack of gas, and Al Taweelah was running at 18% of capacity in September, with EGA expecting to return to pre-war output by early 2027.

LME aluminum reached a four-year high of about $3,665 a tonne in mid-April 2026, and the US Midwest premium, paid on top of the LME price, hit a record $1.10 a pound. The price eased to $3,134 by October 6 as Gulf metal partly returned to the market.

The United States, once the world's largest producer, ran only four of its six primary smelters in 2025, producing 660,000 tonnes, and it imports about 60% of its aluminum, mostly from Canada. The 50% tariff raised American prices without adding a smelter, because a new one needs about $4 billion and a gigawatt or more of cheap power that the data centers also want. EGA and Century Aluminum plan a 750,000-tonne smelter at Inola, Oklahoma, with construction to begin by the end of 2026 and production before 2030, the first new American smelter since 1980.

10c. What the Bulk Metals Teach

The bulk metals are not on most critical lists, since iron ore and bauxite come from many places in vast tonnages, but they teach three things the critical ones share. First, the buyer can be the chokepoint: China's share of seaborne iron-ore imports gives it leverage over Australia and Brazil that no producer cartel ever had, and its financing of Simandou was a decision to break a supplier duopoly.

Second, processing follows energy, and energy can be attacked, since aluminum smelting went to China's coal and the Gulf's gas and in 2026 a war took Gulf metal off the market. Third, producers learn from each other, so Guinea's license revocations, Indonesia's bans and quotas, and the Congo's cobalt rules are one doctrine, the subject of Module 12, applied to the largest trade flows on earth.

Module 10 Key Points

The Bulk Metals: Iron Ore, Bauxite, and Aluminum

• Iron ore is a triangle of Australia, Brazil, and China; the benchmark price fell to $90.68 a tonne in October 2026.

• Simandou shipped its first ore in November 2025 after thirty years; the buyer with capital and patience got the mountain.

• China makes 61% of the world's 74 Mt of aluminum and has reached its own 45 Mt cap.

• Iranian strikes on two Gulf smelters in March 2026 drove LME aluminum to a four-year high of about $3,665.

• The US imports about 60% of its aluminum; a 50% tariff raised prices but has not yet added a smelter.

Module 10 Quiz

Check Your Understanding

1. What is Simandou?

A) A lithium mine
B) A Guinean iron-ore deposit
C) A copper mine in Chile's Atacama desert run by Codelco and BHP
D) A Chinese aluminum smelter built in Indonesia after the bauxite export ban

2. How can the buyer be the chokepoint in a bulk commodity?

A) China's share of seaborne iron-ore imports gives it leverage over the terms of trade
B) It cannot, in a bulk trade
C) By owning the ships
D) By setting tariffs on ore at Chinese ports

3. What drove LME aluminum to a four-year high in April 2026?

A) A bauxite strike in Australia
B) China's new tax on exports
C) A Canadian ban on primary aluminum exports to the United States after the tariff talks failed
D) Iranian strikes on two Gulf smelters

4. Why has the 50% US aluminum tariff not yet added a smelter?

A) Canada won a trade case that suspended the tariff for its producers
B) Aluminum is off the US critical list, so no federal support is available
C) Smelters need cheap power
D) The tariff applies only to scrap, not to primary metal or alumina

5. Which three lessons does the module draw from the bulk metals?

A) The buyer can be the chokepoint, processing follows energy, and producers learn from each other
B) Prices always fall
C) Bulk metals are free markets
D) Cartels set every price

Module 11 — The Battery and Magnet Supply Chains

From Mine to Cell and Magnet, With the Shares at Each Step

Recommended Reading / Reference

Reference: SNE Research's battery installation data for 2025 (February 2026); the IEA's *Energy Technology Perspectives 2026* (March 26, 2026) and *Global EV Outlook 2026*; Benchmark Mineral Intelligence's gigafactory and cathode assessments; the Treasury's guidance on prohibited foreign entities under the July 2025 budget law

11a. The Battery Chain

Step	What it is	China's share	Others	Western capacity (2026)
Mining	Lithium, nickel, cobalt, graphite, manganese ore	Lithium 21%; nickel and cobalt small at home but large through Chinese-owned Indonesian plants and Congolese mines; natural graphite about four-fifths	Australia, Chile, Indonesia, the DRC, Argentina, Zimbabwe	The least concentrated step by country, the most concentrated by ownership
Refining to chemicals	Lithium carbonate and hydroxide, nickel and cobalt sulfate, spherical graphite, manganese sulfate	About two-thirds for lithium, three-quarters for cobalt, more than 90% for graphite, about 95% for manganese sulfate	Chile, Argentina, Korea, Finland; Indonesia, in Chinese-owned plants	Tesla (Texas), Albemarle, Posco, Umicore; Syrah for graphite
Cathode active material	NMC or LFP powder	Most NMC and nearly all LFP	Korea (LG Chem, Posco Future M, EcoPro, L&F); Japan (Sumitomo Metal Mining, Nichia)	Korean joint ventures in North America; LFP lines from 2026
Anode active material	Natural or synthetic graphite, with silicon additives	More than 90%	Korea (Posco), Japan	Syrah, Novonix, Vianode: a small share of need
Electrolyte and separator	Lithium salts and solvents; polymer separators	Most electrolyte; a majority of separators	Japan (Asahi Kasei, Toray), Korea (SK IE Technology)	Small
Cells	The battery cell	Chinese makers about 70% of 2025's electric-car battery installations: CATL 39.2%, BYD 16.4%	Korea about 15% (LG Energy Solution 9.2%, SK On, Samsung SDI); Japan (Panasonic 3.7%)	US plants below capacity since the consumer credit ended in September 2025; several delayed or cancelled
Equipment	Coaters, calenders, winders, formation	Most	Korea, Japan	China's October 2025 controls on battery equipment are suspended under the truce, to January 10, 2027
Recycling	Black mass to chemicals	Most capacity	Korea, Europe, the US (Redwood Materials)	Module 15

SNE Research (installations); IEA; Benchmark; approximate shares for 2025.

The battery is made in China at every step but the mine. The IEA's *Energy Technology Perspectives 2026* finds that between 60% and 100% of each processing and manufacturing step of the battery supply chain sits in China, that China made roughly 80% of all batteries in 2024, and that Chinese production costs can be less than half of those in advanced economies. Chinese, Korean, and Japanese companies make nearly all of the world's lithium-ion cells.

Of the 1,187 GWh of electric-car batteries installed in 2025, by SNE Research's count, CATL alone supplied 39.2% and BYD 16.4%, and Chinese makers together about 70%. Korea's LG Energy Solution, SK On, and Samsung SDI supplied about 15%, and Japan's Panasonic 3.7%, with the remaining tenth spread among smaller makers.

The Western plants built since 2022 are mostly cells and packs made with Asian materials and machines. The American gigafactories, built by Tesla and Panasonic, GM and LG, Ford and SK, Toyota, Hyundai, and Stellantis and Samsung with the manufacturing credit of the 2022 climate law, have run below capacity since the consumer tax credit for electric cars ended on September 30, 2025, and several were delayed or cancelled. Europe's flagship, Northvolt, filed for bankruptcy in March 2025, and the IEA finds that average delivered cell costs in the United States rose about 8% in 2024-25.

11b. The Magnet Chain

Step	China's share	Outside China (2026)	Note
Rare-earth mining	69%	The US (Mountain Pass) 13%; Australia; Myanmar's clays, which go to China; Brazil	—
Separation into oxides	85%; nearly all of the heavy elements	Lynas, MP Materials, Solvay, Neo; Iluka from 2027	The chokepoint
Metal and alloy	Most	Lynas, MP, Neo, Less Common Metals (UK), Vacuumschmelze	Reduction of oxide to metal
Magnet manufacture	About 94% of sintered magnets	Japan (Shin-Etsu, TDK, Proterial); MP (Texas); eVAC (South Carolina); Noveon; USA Rare Earth	Sintering, machining, coating; China controls the know-how and equipment
Motors and products	Chinese motors for cars and turbines; Western automakers buy Chinese magnets	Reduced or rare-earth-free motors	The demand side's escape route

IEA; USGS; company disclosures.

The magnet chain is shorter and more Chinese than the battery's: 69% of the ore, 85% of the separation, and about 94% of sintered magnets, with Japan the only long-established alternative and the American and European plants still small. The chain's product, the neodymium-iron-boron magnet, sits in every electric-car motor at one to two kilograms each, in direct-drive wind turbines, in robots and drones, and in precision weapons.

The April 2025 controls showed that the weakest links are not the ore but the two steps that Chinese policy built and Western neglect abandoned: separation and magnet-making.

11c. Korea, Japan, and the Rules on Chinese Inputs

Korea and Japan are the West's chain. Korea's three cell makers and its cathode makers, Posco Future M, EcoPro, and L&F, are partners in most American and many European gigafactories, while Japan's Panasonic, Sumitomo Metal Mining, Asahi Kasei, Toray, and its magnet makers supply separators, high-nickel cathodes, and magnets that China does not dominate. Both countries buy many of their own inputs from China, which is why American rules on Chinese inputs bind on them.

The July 2025 budget law ended the consumer credits but kept the manufacturing credit for batteries and components, while denying it to companies owned or effectively controlled by 'prohibited foreign entities', Chinese companies among them, and phasing in limits on how much of a product's cost may come from such suppliers. The test cases include Ford's Michigan plant, licensed by CATL to make LFP cells, the Korean ventures' Chinese suppliers, and LFP plants that cannot yet buy non-Chinese phosphate or graphite, and they will decide in 2026-27 whether a non-Chinese chain can be built at a price buyers will pay.

Module 11 Key Points

The Battery and Magnet Supply Chains

• Between 60% and 100% of each battery processing and manufacturing step sits in China, which made about 80% of batteries in 2024.

• CATL supplied 39.2% of 2025's electric-car battery installations, and Chinese makers together about 70%.

• The magnet chain is more Chinese still: 85% of separation and about 94% of sintered magnets.

• Korea and Japan are the West's chain, and both buy inputs from China, so American sourcing rules bind them.

• US gigafactories have run below capacity since the consumer credit ended in September 2025; Northvolt went bankrupt in March 2025.

Module 11 Quiz

Check Your Understanding

1. At which step of the battery chain is China least dominant by country, and why is that misleading?

A) Recycling, where the West leads
B) Mining, but Chinese companies own mines in Indonesia and the Congo
C) Cells, where Korea leads
D) Equipment, which Korean and Japanese machine makers supply to most Chinese gigafactories

2. What share of 2025's electric-car battery installations did CATL supply?

A) About 5%
B) About 60%, with no close rival in China or abroad
C) About 15%, level with LG Energy Solution and Panasonic
D) About 39%

3. What are the weakest links in the magnet chain?

A) Separation and magnet-making
B) The ore, which is mined only in China and Myanmar
C) Motor assembly, which Japanese automakers keep at home
D) Recycling, since end-of-life magnets cannot be separated from the motors that hold them

4. Why do American rules on Chinese inputs bind on Korean and Japanese companies?

A) They export cells to China
B) They buy many inputs from China
C) They are Chinese-owned companies registered in Seoul and Tokyo
D) The rules apply only to companies headquartered outside North America

5. What happened to the American gigafactories after September 2025?

A) CATL bought them
B) They closed
C) They ran below capacity after the consumer credit ended, and several were delayed
D) They ran at full capacity on grid-storage orders after the credit ended in September 2025 and the tariffs rose

Module 12 — Producer Power: The New Resource Nationalism

The Quotas, Bans, and State Venues Producers Now Use

Recommended Reading / Reference

Reference: IEA, *Global Critical Minerals Outlook 2026* (export restrictions); the inventory of export restrictions on industrial raw materials kept by the Organisation for Economic Co-operation and Development (OECD); the decrees of the DRC, Indonesia, Zimbabwe, Guinea, and Chile, 2023-26

Producer	Mineral (share)	Instrument	Date	Effect on price	Effect on investment
China	Rare earths, graphite, gallium, germanium, antimony, tungsten, indium, silver, battery technology	Export licensing; technology controls; an extraterritorial rule (suspended); general licenses for chosen buyers	2023-26	Heavy rare earths at many times China's price outside China; tungsten up more than fourfold between January and July 2026	Western floors, stakes, and offtakes in response
The DRC	Cobalt (73%), copper concentrate	An export suspension (February 2025), then quotas of 96,600 tonnes a year for 2026-27 with a strategic reserve; routine concentrate waivers ended by an order of June 29, 2026	2025-26	Cobalt more than doubled	Refining forced into the country
Indonesia	Nickel (67%), bauxite, tin	Ore-export bans (nickel 2020, bauxite 2023); 2026 quotas cut to 260-270 million wet tonnes; a mineral exchange due by January 2027	2020-27	Nickel from about $14,000 to above $17,000 by February 2026, before easing	Processing built in the country by Chinese capital
Zimbabwe	Lithium (10%)	A raw-ore ban (2022); concentrate exports suspended (February 2026), then quotas for producers that commit to sulfate plants; a concentrate ban from January 2027	2022-27	Modest	Chinese owners building refineries
Guinea	Bauxite (34%), iron ore (Simandou)	License revocations (2025); refinery conditions; state stakes	2025-26	Bauxite firm	The refinery mandate
Chile	Lithium (19%), copper (23%)	The 2023 National Lithium Strategy: state control of new brine projects; the Codelco-SQM venture	2023-26	—	Investment slowed; Argentina gained
Mexico	Lithium	Nationalized (2022); concessions cancelled	2022-25	—	No production
Namibia, Ghana, Mali, Tanzania, and others	Lithium, graphite, gold	Raw-export bans, local-processing rules, state stakes in new mining codes	2023-26	—	The template spreading
The United States	Tungsten scrap and black mass	Exports restricted for a year from August 2026; price floors; equity stakes; a reserve	2025-26	Floors above market	Module 13

12a. The Doctrine

The critical-minerals market of 2026 is less a market than a network of managed channels, and the producers wrote the doctrine. It has five elements:

- **Ban the raw form:** a ban or quota on ore, concentrate, or an intermediate product forces processing into the country.
- **Calibrate the quota:** volumes are set to lift the price rather than to clear the market.
- **Hold a reserve:** the state keeps a strategic stock against its own quota.
- **Capture the margin:** a state marketing body or price venue takes the margin that traders once took.
- **Bind the builders:** ownership and capital rules apply to the foreign, usually Chinese, companies that built the processing.

The Congo's cobalt regime is the purest case: a suspension, then a quota at well under half of output, a reserve, an end to routine concentrate waivers, and a price that more than doubled. Indonesia's nickel regime is the largest, a dozen years from its first ore ban, in 2014, to two-thirds of world supply to quota cuts meant to end the glut its own policy created. China's is the model both learned from, and it runs on licenses rather than volumes, so the threat can be aimed at a buyer rather than spread across a market.

12b. Why It Works, and Where It Does Not

Producer power works where three conditions hold. The producer's share must be too large to replace in the time a buyer can wait, as with the Congo's 73% of cobalt, Indonesia's 67% of nickel, and China's 85% of rare-earth refining. Demand must be inelastic in the short run, since a cathode plant cannot switch chemistry in a year and a missile cannot use less dysprosium, and the state must be able to enforce the rule against its own miners and against smugglers.

It fails where substitution is fast, as cobalt's falling share of cathodes shows, where the share is contestable, as with Zimbabwe's tenth of lithium, or where the buyer is the chokepoint, as with Guinea's bauxite and a China that can also buy Australian ore. The returns are visible: cobalt more than doubled on a quota decree, and nickel rose by a fifth on a permit document. Since 2025 the Congo, Indonesia, and Zimbabwe have each tightened again, because the gains reach the state budget in the first year and the costs, lost investment and substitution, arrive years later.

12c. What It Does to Prices and Investment

Managed scarcity raises prices inside the managed channel and lowers investment outside it. Buyers pay more, from the cobalt squeeze's extra $165 million a year for one cathode maker to dysprosium at 16 times the Chinese price for buyers outside China. The price no longer tells an investor where to build, because a Western mine cannot know whether the price it needs will exist when it opens: the Congo could lift its quota, China could resume licenses, and Indonesia could reopen its taps, and each has done so before.

The IEA's finding that investment in new supply fell 9% in 2025, even as prices rebounded, is the doctrine's cost. Capital that cannot price the policy risk stays out, the deficits of the 2030s deepen, and the producers' share rises further. The Western answer, in Module 13, is to replace the market's signal with the state's through floors, offtakes, and equity, which is the same doctrine from the other side.

Module 12 Key Points

Producer Power: The New Resource Nationalism

• The producers' doctrine: ban the raw form, set quotas to lift prices, hold reserves, capture traders' margins, and bind foreign builders.

• The Congo's cobalt regime is the purest case, Indonesia's nickel regime the largest, and China's licensing the model.

• It works with an irreplaceable share, inelastic demand, and enforcement; it fails against substitution, contestable shares, and buyer power.

• Since 2025 the Congo, Indonesia, and Zimbabwe have each tightened again, because gains come in year one and costs later.

• Managed scarcity lifts prices but deters investment: the IEA found investment fell 9% in 2025 despite rebounding prices.

Module 12 Quiz

Check Your Understanding

1. What are the elements of the producers' doctrine?

A) Free trade in ore
B) A producers' cartel modeled on OPEC
C) Nationalization of every mine
D) A ban on raw exports, a price-lifting quota, a reserve, a state price venue, and rules on foreign builders

2. Which regime does the module call the purest case of the doctrine?

A) Chile's lithium strategy
B) Mexico's 2022 nationalization
C) The Congo's cobalt quota and reserve
D) Zimbabwe's 2026 suspension of lithium concentrate exports and its sulfate-plant quotas

3. Where does producer power fail?

A) Where prices are already high enough to draw new supply from rivals within a year
B) Where the producer holds less than half of world output
C) Where China itself is the producer of the metal in question
D) Where substitution is fast

4. Why have more producers tightened their rules since 2025?

A) The WTO now permits quotas
B) The gains reach the state budget in the first year, while the costs of lost investment and substitution come years later
C) China demanded it of them
D) Prices were falling everywhere

5. Why does managed scarcity lower investment outside the managed channel?

A) Policy can reverse the price
B) Miners prefer China
C) Environmental rules tightened at the same time in every Western country
D) Prices fall under management, so no new mine can earn its capital

Module 13 — The American Response

The US Playbook, and What Has Actually Been Built

Recommended Reading / Reference

Reference: The executive orders of March and April 2025 on mineral production and seabed minerals; Proclamation 11001 on processed critical minerals (January 14, 2026); the Defense Department's agreement with MP Materials (July 10, 2025); the July 2025 budget law; the Export-Import Bank's Project Vault (February 2026); the White House fact sheet of August 7, 2026; Columbia University's Center on Global Energy Policy on Project Vault (June 2026)

Instrument	What it does	Examples (2025-26)	Assessment
Price floors	Guarantee a domestic producer a minimum price	MP Materials: $110 a kilogram for NdPr for ten years (July 2025); floors in Lynas's contracts with Japanese and American buyers; floors proposed in the trade talks under Section 232	The most direct answer to Chinese pricing; with NdPr prices below $110, the floor paid MP $59.9 million in the first half of 2026
Equity stakes	Make the government a shareholder	MP Materials, about 15% for $400 million (July 2025); Lithium Americas and Thacker Pass, 5% each (October 2025); Trilogy Metals, 10% (October 2025); Vulcan Elements (November 2025); USA Rare Earth, shares and warrants (June 2026)	State capital's return
Offtake and procurement	Make the government or a contractor the buyer	MP's magnet offtake; Pentagon contracts with Perpetua and Almonty; Lockheed Martin's scandium and germanium talks (August 2026)	Certainty of demand for plants that could not otherwise be financed
Loans and grants	Lend or grant through the Energy Department, the Export-Import Bank (EXIM), the Development Finance Corporation (DFC), and the Defense Production Act	Thacker Pass ($2.23 billion); Perpetua ($2.9 billion approved by EXIM, May 2026); the August 7, 2026 package of more than $2 billion	The White House counts about 160 minerals deals worth almost $40 billion since January 2025
Project Vault	A strategic reserve run with commodity traders	A $10 billion EXIM loan and about $2 billion of private capital (February 2, 2026); Hartree, Traxys, and Mercuria as traders; manufacturers pay fees for access; any of the 60 listed minerals eligible	Purchase rules unpublished by mid-2026; EXIM's authorization expires December 31, 2026
The National Defense Stockpile	The Pentagon's own reserve	$2 billion from the July 2025 budget law; a $300 million lithium tender cancelled (August 2026)	Months of defense supply, not civilian supply
Tariffs and Section 232	National-security tariffs on imports	50% on semi-finished copper (August 2025) and on aluminum and steel (June 2025). Proclamation 11001 (January 14, 2026): no tariff on processed minerals for now; negotiations and price floors instead	Raise domestic prices without adding capacity where power and permits are the constraint
Rules on Chinese inputs	Deny manufacturing credits to products with prohibited foreign content	The July 2025 budget law	The mechanism for a non-Chinese battery chain
Export controls	Keep scrap at home	Tungsten scrap and black mass, for one year from August 2026	A mutual embargo managed by exception

Instrument	What it does	Examples (2025-26)	Assessment
Permitting	Priority status for chosen projects	Resolution Copper's land transfer (March 16, 2026); the FAST-41 coordination process; a House package led by the Critical Mineral Dominance Act, passed 224-195	Faster paper; the courts and the tribes still decide
Deals abroad	Access to foreign deposits in exchange for security or aid	Ukraine (April 30, 2025); Australia (October 20, 2025, an $8.5 billion pipeline); Japan (October 2025); Kazakhstan's tungsten (November 2025); the DRC (December 4, 2025); MP Materials with Saudi Arabia's Ma'aden	Access to ore rather than processing; a decade from output
Agreements with allies	Shared price floors	Action plans with the European Union and Japan (February 2026) toward a plurilateral agreement with border-adjusted price floors	Not yet binding

Government and company announcements; Columbia University's Center on Global Energy Policy. FAST-41 is the federal permitting-coordination process created by a 2015 law.

13a. The Playbook

The United States' response has moved from grants, the manufacturing credits and Energy Department loans of 2022-24, to something close to the producers' doctrine in mirror image. Price floors guarantee a domestic producer the price that Chinese competition denies, equity stakes make the government a shareholder, and offtakes make it the customer. A reserve makes it the buyer of last resort, tariffs protect the finished metal, sourcing rules shut Chinese chains out of the subsidized market, export controls keep scrap at home, and deals abroad trade security or aid for access.

On August 7, 2026 the White House hosted a roundtable for more than 100 mining executives, BHP and Rio Tinto among them, and announced more than $2 billion of new deals. They included $1.4 billion for Sila Nanotechnologies' anodes and cell plant, $400 million for Sunrise Energy Metals' scandium, and $150 million for Niron Magnetics' rare-earth-free magnets, and the White House counted about 160 minerals deals worth almost $40 billion since January 2025.

13b. The Template: The MP Materials Deal

The template is the agreement that the Department of Defense, styled the Department of War since September 2025, signed with MP Materials on July 10, 2025. MP owns the Mountain Pass mine, had been losing money on Chinese prices, and until April 2025 shipped most of its concentrate to China for separation.

The Pentagon bought preferred stock and warrants worth $400 million, about 15% of the company, guaranteed a price of $110 a kilogram for its NdPr for ten years, and committed to buy all the magnets from a new 10,000-tonne plant for ten years, with bank financing to build it. Apple followed within days with a $500 million agreement for magnets made from recycled material.

It was the first American price floor and equity stake in a critical mineral since the Cold War, and within months the model spread to lithium, copper exploration in Alaska, magnets, and rare-earth mining. It also showed the cost, and who sets it. The floor pays MP the gap between $110 and the market price, which is set in China, so with NdPr below $110 it paid $59.9 million in the first half of 2026, $17.6 million of it in the second quarter.

13c. Floors and Stakes: The Argument

The case for the state as investor. Supporters, in the administration and in both parties in Congress, argue that China sets mineral prices by policy, so no private market can finance a Western refinery against them. A floor answers a policy price with a policy price, and a stake lets taxpayers share the upside of risks they already bear. The April 2025 halt showed the cost of waiting, when production lines stopped within weeks and the defense supply chain turned out to run through the adversary.

The case against. Critics, including free-market economists and some investors, argue that the state picks winners it cannot judge and creates a lobby for permanent support. Floors pay most when markets are oversupplied, which rewards the wrong plants, and stakes in a few listed companies invite conflicts of interest. Columbia University's Center on Global Energy Policy warns that Project Vault's three aims, a stockpile, a market-maker in thin markets, and a buyer for manufacturers, conflict, that traders running it may profit from the volatility it is meant to calm, and that a reserve of raw ore is of little use without processing.

The evidence. The tools have bought capacity: MP produced 840 tonnes of NdPr oxide in the second quarter of 2026 and has started making magnets, and dozens of projects now have financing they lacked in 2024. But the floor's cost is set by Chinese pricing, $59.9 million in the first half of 2026, Project Vault had not published its purchase rules by mid-2026, and the Pentagon cancelled its own lithium tender. The IEA counts $65 billion of public finance commitments over 2023-25, a fourfold rise, against investment in new supply that fell 9% in 2025.

The course's reading. The instruments fit the refining problem better than grants for mines did, because the obstacle is a price set by policy. Their risk is less waste than incoherence: stockpiles, floors, and stakes bought in the wrong order, competing with allies for the same scarce output.

13d. What Has Actually Been Built

Project	Mineral	Status (October 2026)	Government role
MP Materials (California; Texas)	Rare earths and magnets	NdPr output of 840 tonnes in the second quarter of 2026; magnets since December 2025; commercial magnets from the larger plant due in late 2026; a heavy-element circuit being commissioned	About 15% stake; $110 floor; magnet offtake
Lynas, Seadrift (Texas)	Heavy rare earths	In doubt since 2025; heavy elements come from Malaysia instead	Pentagon funding
USA Rare Earth (Oklahoma; Texas)	Magnets; rare-earth mining	Magnet plant ramping; Round Top targeted for 2028	Up to $1.6 billion from the Commerce Department; shares and warrants
Thacker Pass (Nevada)	Lithium from clay	Under construction; first production targeted for late 2027	$2.23 billion loan; 5% stakes
Syrah, Vidalia (Louisiana)	Graphite anodes	Operating below capacity	Energy Department loan
Perpetua, Stibnite (Idaho)	Antimony and gold	A final investment decision due in the second half of 2026	Pentagon grants; a $2.9 billion EXIM loan approved in May 2026
Resolution Copper (Arizona)	Copper	Land transferred March 16, 2026; drilling and underground contracts awarded; production years away	Priority permitting
Almonty, Sangdong (Korea)	Tungsten	Processing since July 2026	An American buyer, Global Tungsten & Powders

Project	Mineral	Status (October 2026)	Government role
Rio Tinto (Quebec); 5N Plus (Utah)	Gallium; germanium	Pilot to small commercial scale	Grants
Redwood Materials (Nevada, South Carolina)	Recycling to battery materials	The largest recycler outside China	—
The stockpile and Project Vault	Many	Stockpile purchases under way; Vault's first funding tranche being closed in mid-2026	$2 billion; a $10 billion EXIM loan

What has been built is real, and it is a fraction of need. It includes a rare-earth base at MP, a lithium mine a year from production, a graphite plant running below capacity, an antimony mine awaiting its investment decision, a copper mine a decade away, a recycling industry, and a stockpile being rebuilt.

The copper, nickel, and cobalt gaps close only through allies (Module 14) and through the chemistry shifts that reduce demand (Module 15), and a supply base that would survive a Chinese cutoff remains a project for the mid-2030s.

Module 13 Key Points

The American Response

• Washington moved from grants to the producers' doctrine in mirror image: floors, stakes, offtakes, reserves, tariffs, and export controls.

• The July 2025 MP deal set the template: a 15% stake, a ten-year $110 floor, and a magnet offtake.

• Project Vault pairs a $10 billion EXIM loan with about $2 billion of private capital; its purchase rules were unpublished by mid-2026.

• Supporters call floors and stakes the only answer to policy prices; critics call them picking winners; the evidence supports parts of both.

• What has been built is real but small; a supply base that survives a Chinese cutoff is a mid-2030s project.

Module 13 Quiz

Check Your Understanding

1. What did the Pentagon's July 2025 deal with MP Materials include?

A) A 15% stake, a $110 floor, and a magnet offtake
B) A ban on Chinese magnets
C) A tariff on Chinese NdPr oxide
D) A joint venture with Lynas to separate heavy rare earths in Texas, financed by the Energy Department

2. What is Project Vault?

A) A Pentagon gold reserve
B) A tariff on processed minerals
C) A permitting program for mines
D) A strategic minerals reserve funded by a $10 billion EXIM loan and about $2 billion of private capital, run with commodity traders

3. What did Proclamation 11001 of January 14, 2026 decide on processed critical minerals?

A) A 25% tariff
B) A ban on Chinese processed minerals from 2027, with no exemptions for allies
C) No tariff for now; negotiations instead
D) A 50% tariff on all processed minerals and their derivative products from every country

4. Why did MP's price floor pay out in the first half of 2026?

A) China banned exports of NdPr to the United States in May 2026
B) NdPr prices stayed below $110
C) MP sold its output to Apple at a discount under their recycling deal
D) Congress raised the floor to $150 a kilogram in the defense bill

5. What does the course conclude about the floors and stakes?

A) They are a waste, since markets will solve the refining problem on their own within a few years
B) They have already ended dependence on China for the light and heavy rare earths alike
C) They should give way to tariffs, which add capacity faster than any subsidy can
D) They fit the problem; incoherence is the risk

Module 14 — Allies, Rivals, and the Global South

Europe, Japan, Australia, Canada, India, and the Producers' Deals

Recommended Reading / Reference

Reference: The European Union's Critical Raw Materials Act (2024) and its RESourceEU plan (December 3, 2025); the Japan Organization for Metals and Energy Security; the US-Australia critical-minerals framework (October 20, 2025); Canada's Critical Minerals Strategy (2022); India's National Critical Mineral Mission (2025); the Minerals Security Partnership; the Lobito Corridor's financing documents

Country or bloc	Position	Instruments	2025-26	Assessment
European Union	The largest importer with the least mining; nearly all its rare earths and magnets from China	The Critical Raw Materials Act's 2030 targets; 47 strategic projects designated in March 2025 and 13 abroad in June; RESourceEU (December 2025): up to €3 billion within a year, a center for joint purchasing and stockpiling, and curbs on exports of magnet scrap from early 2026	Hit hardest by the April 2025 halt; Solvay's restart in France; Neo's magnet plant in Estonia; Serbia's Jadar lithium project contested	More money than before, still short of the targets
Japan	The 2010 lesson; the model stockpiler	JOGMEC investment in Lynas, Australian projects, and Brazil; national stockpiles of rare metals; trading-house offtakes; magnet makers (Shin-Etsu, TDK, Proterial)	China's January 2026 ban on dual-use exports to Japanese military users; an American plea in June rejected; rare-earth mud retrieved from the deep seabed in a February 2026 test	The best-prepared consumer, still exposed on the heavy elements
Australia	The largest lithium miner; a top producer of rare earths, iron ore, and bauxite	The Critical Minerals Strategy; a strategic reserve of A$1.2 billion; the October 2025 framework with the US, an $8.5 billion pipeline; loans to Iluka, Lynas, and Arafura	Nickel mines idled by Indonesian prices; lithium mines restarting in 2026	The West's mine, trying to become its refinery
Canada	Nickel, cobalt, uranium, graphite, lithium in Quebec, potash	The Critical Minerals Strategy (C$3.8 billion, 2022); limits on Chinese takeovers	Tariff fights with the US; aluminum shipments south still below pre-tariff levels	Allied supply across a tense border
South Korea	The battery and cathode maker	State stockpiles; Posco's lithium and nickel investments abroad; Almonty's tungsten mine	Partner in US gigafactories, exposed to US sourcing rules and Chinese inputs alike	The West's factory and China's customer
India	A rising consumer and would-be refiner	The National Critical Mineral Mission (2025); overseas acquisitions; a rare-earth magnet incentive scheme (November 2025)	Hit by China's 2025 rare-earth curbs	A future refiner with today's dependence
The Minerals Security Partnership	The Western coordinating forum: 14 countries and the EU	Project endorsements; a finance network	Slowed by the members' 2025 tariff fights	A forum, not a fund
Global South producers	The DRC, Indonesia, Zimbabwe, Guinea, Chile, Argentina, Brazil, Kazakhstan, Saudi Arabia	Quotas, processing mandates, state stakes, and deals with both blocs	The leverage of Module 12	Selling access to the highest bidder, usually China

Country or bloc	Position	Instruments	2025-26	Assessment
The Lobito Corridor	A rail route from the Congo and Zambia to Angola's Atlantic coast	US, EU, and African Development Bank finance	The flagship Western infrastructure project in Africa	The one Western bet that bypasses Chinese logistics

14a. The Allies

The West's allies divide into consumers and producers, and neither group is where it needs to be. Europe is the most exposed consumer, buying nearly all its rare earths and magnets from China. Its Critical Raw Materials Act of 2024 set 2030 targets of 10% of its needs mined at home, 40% processed, 25% recycled, and no more than 65% of any strategic material from one country, with project designations but little money. The April 2025 halt idled European auto suppliers first.

The Commission's RESourceEU plan of December 2025 added up to €3 billion within a year for projects that can deliver supply quickly, a European Critical Raw Materials Centre to organize joint purchasing and stockpiling, and restrictions on exports of permanent-magnet scrap from early 2026. It claims the measures could cut strategic dependencies by up to half by 2029.

Japan is the best-prepared consumer, with national stockpiles and the JOGMEC investment that created Lynas after 2010, and in February 2026 it retrieved rare-earth-rich mud from the deep seabed near the remote island of Minamitorishima in a test mission. It was still squeezed in 2026, when China banned dual-use exports, rare earths among them, to Japanese military users and refused an American request in June to restore them.

Australia is the West's mine, for lithium, rare earths, iron ore, and its idled nickel, and under its October 2025 framework with the United States, an $8.5 billion pipeline of projects, and its own A$1.2 billion strategic reserve, it is trying to become the West's refinery through Iluka, Lynas, and Arafura. Canada and Korea complete the set: allied nickel, cobalt, uranium, and graphite across a tense border, and a battery industry exposed to both American rules and Chinese inputs.

14b. The Global South's Leverage

The producing countries of the Global South have learned that a critical mineral is a negotiating position. The Congo signed a strategic partnership with the United States on December 4, 2025, alongside a peace accord with Rwanda, while requiring that its ores be processed at home. Indonesia trades market access for processing and now for ownership, Zimbabwe and Guinea trade export permission for refineries, and Kazakhstan sells tungsten deals to the United States while much of its processing runs through Russia and China.

Saudi Arabia, through Ma'aden, buys into partnerships such as a rare-earth venture with MP Materials, and Brazil's ionic clays, rich in heavy rare earths, draw American and Japanese buyers. The pattern is that access goes to the highest bidder, and the bidder is usually China, which has the capital, the plants to send the ore to, and no conditions about governance. That is why the Western answer has been infrastructure, above all the Lobito Corridor's railway to the Atlantic, and finance through the DFC and the EU's Global Gateway more than mines.

14c. The Coordination Problem

The West's problem is less a shortage of programs than a surplus of uncoordinated ones. The Minerals Security Partnership, the forum meant to align fourteen countries and the EU, slowed in 2025 when its members were fighting each other over tariffs, and American floors and stockpile purchases compete with allied buyers for the same scarce output from outside China. Europe's targets outrun its money, and the analysts' warning is that the West will finance the chain in the wrong order, mines before refineries and stockpiles before plants that can use them.

The producers' doctrine of Module 12 is coherent. The consumers' response is still a set of national programs that has not yet become one.

Module 14 Key Points

Allies, Rivals, and the Global South

• Europe imports nearly all its rare earths from China; its 2030 targets now have RESourceEU's €3 billion, still short of need.

• Japan, the model stockpiler since 2010, was still squeezed when China cut dual-use exports to its military in January 2026.

• Australia, with an $8.5 billion US framework and a A$1.2 billion reserve, is trying to turn its mines into refineries.

• Global South producers sell access to the highest bidder, usually China, which brings capital, processing, and no conditions.

• The West's problem is a surplus of uncoordinated programs that compete for the same scarce output outside China.

Module 14 Quiz

Check Your Understanding

1. Why is the European Union described as the most exposed consumer?

A) It mines too much
B) It imports nearly all its rare earths from China
C) It banned Chinese mineral imports at the border in 2025 and lost access to processing
D) It has no battery industry left to protect, after Northvolt's bankruptcy closed every plant

2. What did the EU's RESourceEU plan of December 2025 include?

A) A ban on Chinese magnets
B) A tariff on lithium imports
C) Up to €3 billion within a year, a center for joint purchasing and stockpiling, and curbs on exports of magnet scrap
D) A cartel with Chile and Australia

3. What did Japan retrieve in a February 2026 test mission?

A) Rare-earth mud from the deep seabed
B) Lithium brine
C) Gallium from scrap
D) Cobalt nodules from the Clarion-Clipperton Zone under a US permit issued to a mining company

4. To whom do Global South producers usually sell access, and why?

A) The United States, for its security guarantees and its offtakes
B) Europe, for its finance and its standards on labor and environment
C) China: capital, processing, no conditions
D) Japan, for its long-term contracts and its stockpile purchases

5. What is the West's coordination problem?

A) Too few programs
B) Programs that compete for the same output
C) One overpowered agency in Washington that sets every ally's purchasing
D) Allies that refuse to fund any mineral projects outside their own borders

Module 15 — Recycling, Substitution, and Demand Destruction

The Ways Out of Dependence That Do Not Involve Mines

Recommended Reading / Reference

Reference: The IEA's *Recycling of Critical Minerals* (2024) and *Global Critical Minerals Outlook 2026*; Rho Motion's battery data; Fastmarkets on black-mass capacity; Redwood Materials' disclosures; the White House fact sheet of August 7, 2026; General Motors' and Peak Energy's sodium-ion announcement (June 2026)

15a. Recycling

Metal	Recycled share of supply	Why	Outlook	Leaders
Aluminum	About a third	Remelting uses about 5% of the energy of primary metal; cans and buildings recycle well	Rising	Novelis, Norsk Hydro
Copper	About a sixth of refined output, about 5 Mt	Valuable, easy to identify, long-lived products such as cables and buildings	The largest single new source after Chile	Aurubis, Glencore, Chinese refiners
Nickel	About a third, mostly stainless-steel scrap	Stainless scrap is a mature market; battery scrap is small	—	Stainless mills
Cobalt	About a tenth	High value makes recovery pay	Rising	Umicore, Glencore, CATL's Brunp
Lithium	A few percent	Batteries are only now reaching the end of their lives; recovering lithium is costly; recycling LFP cells pays poorly	A tenth or more from retiring car batteries in the 2030s	Redwood Materials, Brunp, Umicore, SungEel
Rare-earth magnets	Under 1%	Magnets are small, glued into products, and hard to recover	Magnet-to-magnet recycling at small scale	Noveon, HyProMag, Cyclic
Gallium, germanium, indium	Small, mostly from manufacturing scrap	Dispersed uses; byproduct economics	Modest	Umicore, Japanese refiners
Tungsten	About a third	Hard-metal scrap is a mature loop	US scrap kept at home from August 2026	Global Tungsten & Powders
Battery black mass	—	Scrap from gigafactories is the near-term feedstock; end-of-life volume arrives in the 2030s	The 2030s' resource	China holds most capacity; the US about 9% (early 2026)

IEA, USGS, and Fastmarkets; shares approximate.

Recycling is the mine that needs no permit, and its contribution runs from large for aluminum and copper, where scrap supplies about a third and a sixth of the metal, to negligible for rare-earth magnets and lithium. The battery loop is the energy transition's promise and its timing problem: end-of-life car batteries arrive in volume only in the 2030s, since a pack lasts twelve to fifteen years, so recyclers built for them run today on scrap from gigafactories and face a Chinese industry with most of the world's capacity.

Li-Cycle's collapse in 2025, after which Glencore bought its assets, showed the economics: with lithium near $10,000 a tonne and cobalt near $22,000, recycling did not pay. At 2026's higher prices it pays for nickel-cobalt cells and still struggles for LFP, whose iron and phosphate are worth little. In August 2026 the United States restricted exports of black mass for a year to keep the feedstock at home, where recycling capacity was about 9% of the world's early in the year, by Fastmarkets' estimate.

Recycling's honest role is a tenth or more of the battery metals by the mid-2030s, a large share of copper and aluminum now, and almost none of the rare earths and minor metals whose dependence matters most for defense.

15b. Substitution

Dependence	Substitute	Status (2026)	Effect	Limit
Cobalt and nickel in cathodes	LFP; high-nickel NMC; LMFP	LFP about half of electric-car batteries and nearly all grid batteries by 2025	Cobalt's demand growth cut; nickel's battery share falling	Lower energy density; LFP's chain is even more Chinese
Lithium	Sodium-ion cells, using sodium, iron, and manganese	CATL's Naxtra line; GM and Peak Energy developing sodium-ion cells for grid storage (June 2026)	Marginal now	Lower density; an advantage only when lithium is dear
Rare-earth magnets in motors	Induction and wound-rotor motors (BMW, Renault), ferrite magnets, iron-nitride magnets, designs with less dysprosium	Commercial in some models; $150 million for Niron's iron-nitride magnets (August 2026)	Less NdPr per vehicle where adopted	Efficiency and size penalties; no substitute for the heavy elements in defense
Copper in wiring	Aluminum, with about 60% of copper's conductivity and a third of its weight	Standard in power lines; growing in cars and buildings	Caps copper's price relative to aluminum's	Corrosion and the reliability of joints
Gallium in chips	Silicon carbide; silicon	Partial, in power electronics	Small	Gallium nitride's radar uses have no substitute
Germanium in optics	Chalcogenide glass	Partial	Small	Infrared performance
Antimony in flame retardants	Other retardants	Partial	Modest	Ammunition primers have none
Tungsten in tools	Ceramics and coated steels	Partial	Modest	Penetrators have none

Substitution has been the most effective response to every mineral squeeze in history, and the 2020s confirm it. The cobalt scares of 2018 and 2022 produced high-nickel and then LFP chemistries that cut cobalt's demand growth, the rare-earth crisis of 2010 produced magnets with less dysprosium and motors with no magnets at all, and copper's price is capped by aluminum's.

Sodium-ion cells, which need no lithium, cobalt, or nickel, are the answer being prepared for the next lithium spike: CATL has launched a sodium-ion line, and in June 2026 General Motors said it would develop sodium-ion cells for grid storage with Peak Energy. In August 2026 the Pentagon committed $150 million to Niron Magnetics, which makes iron-nitride magnets that contain no rare earths.

The limits are in the table's last column. The heavy rare earths in a missile's actuator, the gallium in a radar, the antimony in a primer, and the tungsten in a penetrator have no substitutes, which is why the defense minerals of Module 9, more than the battery metals, are where dependence is hardest.

15c. Demand Destruction and the Chemistry Shift

The energy transition's mineral demand moves down as fast as it moves up. Cobalt's battery demand has been revised down repeatedly as LFP took share, nickel's has fallen behind the forecasts, lithium's rose on storage and fell on slower Western electric-car sales, and the rare earths' fell per vehicle while rising with robots, drones, and data-center cooling. Between its 2025 and 2026 Outlooks, the IEA's projected gaps for copper and lithium over the next decade narrowed.

The lesson for the producers of Module 12 is that a squeeze speeds its own undoing, so the Congo's cobalt quota is the best advertisement that sodium-ion and LFP cells ever had. The lesson for the West is that the cheapest response to a chokepoint is often a chemistry change in a factory rather than a mine in a desert, except for the elements no chemistry can replace, which are the ones China controls most completely.

Module 15 Key Points

Recycling, Substitution, and Demand Destruction

• Scrap supplies about a third of aluminum and a sixth of copper, but under 1% of rare-earth magnets and little lithium.

• Car batteries reach the end of their lives in volume only in the 2030s; Li-Cycle's 2025 collapse showed the economics.

• LFP cells, half of electric-car batteries by 2025, cut cobalt demand; sodium-ion cells are being readied for the next lithium spike.

• Rare-earth-free magnets won $150 million of Pentagon support in 2026, but heavy rare earths in weapons have no substitute.

• A squeeze speeds its own undoing: the Congo's quota is the best advertisement cobalt-free cells ever had.

Module 15 Quiz

Check Your Understanding

1. For which metals is recycling a large source of supply, and for which is it negligible?

A) Large for rare earths; negligible for copper
B) Large for every critical metal
C) Negligible for every metal
D) Large for aluminum and copper; negligible for rare-earth magnets and lithium

2. What did Li-Cycle's 2025 collapse show?

A) Recycling did not pay at low metal prices
B) Batteries cannot be recycled
C) China banned its process
D) That end-of-life batteries had flooded North America years ahead of forecasts, overwhelming every plant

3. What has been the most effective response to mineral squeezes in history?

A) Government stockpiles built in advance of each squeeze and released on demand
B) New mines opened quickly in allied countries with state finance and fast permits
C) Substitution
D) Tariffs on the producer that caused the squeeze, imposed by every consumer at once

4. Which of these dependences has no substitute?

A) Cobalt in cathodes
B) Copper in wiring
C) Lithium in every battery chemistry now sold, including sodium-ion cells for grid storage
D) Heavy rare earths in a missile's actuator

5. What does the module call the Congo's cobalt quota?

A) A model for copper
B) The best advertisement that sodium-ion and LFP cells ever had, because a squeeze speeds its own undoing
C) A failure within a year
D) A permanent solution

Module 16 — Prices, Markets, and Finance

How Minerals Are Priced and Paid For

Recommended Reading / Reference

Reference: The contract specifications of the LME and CME Group; Fastmarkets' and Benchmark's price methodologies; the independent review of the LME's March 2022 nickel crisis by Oliver Wyman (2023); the investment chapter of the IEA's *Global Critical Minerals Outlook 2026*; Wheaton Precious Metals and Franco-Nevada on streaming

16a. How Minerals Are Priced

Mineral	Price venue	Contract	Transparency	Note
Copper, aluminum, zinc, nickel, lead, tin, cobalt	The LME, owned by Hong Kong Exchanges and Clearing since 2012; COMEX in New York; the Shanghai Futures Exchange	Futures with physical delivery to warehouses; the LME's three-month contract is the world benchmark	High for the base metals; thin for cobalt	The 2022 nickel crisis; the 2025-26 split between New York and London copper
Lithium carbonate and hydroxide	Assessed prices from Fastmarkets, Benchmark, and Asian Metal; the Guangzhou Futures Exchange's carbonate contract (2023)	Contracts indexed to assessments; Guangzhou the most liquid market	Improving; China's exchange sets the tone	The May 2026 spike above 200,000 yuan began in Guangzhou
Cobalt	Assessed prices; the LME contract	Contracts indexed to assessments; the DRC's quota allocations	Moderate	The 2026 standoff over hydroxide
Rare earths	Assessments of Chinese trades (Asian Metal, Shanghai Metals Market) and of trades outside China (Benchmark); no exchange; the Pentagon's $110 floor as a parallel price	Bilateral and opaque; two tiers since 2025	Low	The floor above the market price in China and outside it (September 2026)
Graphite, manganese, gallium, germanium, antimony, tungsten	Assessments; bilateral deals	Opaque, in small markets	Low	Prices moved most by export controls
Iron ore	Assessments of 62% ore delivered to China by Platts and Fastmarkets; futures in Singapore and Dalian	Index-linked contracts since 2010	High	The largest metals trade by value
Gold, silver, platinum, palladium	The London Bullion Market Association's prices; COMEX; Shanghai	Deep futures markets	High	Silver's records in 2025-26; China's licensing of silver exports

The base metals have the most transparent prices in commodities: the LME's daily settlements for copper, aluminum, nickel, and zinc, backed by physical delivery to a global network of warehouses, with COMEX and Shanghai as the American and Chinese mirrors. Most critical minerals have nothing like it. Lithium, cobalt, graphite, manganese, and the rare earths trade on bilateral contracts indexed to prices that reporting agencies assess from surveyed deals, and since the 2025 controls the rare earths have had two price tiers, one inside China and one outside it.

Price-setting is moving east. China's Guangzhou Futures Exchange, whose lithium-carbonate contract launched in 2023, became the world's most liquid lithium market, and Indonesia's planned mineral exchange aims to make Jakarta a 'price setter' for nickel.

16b. The Nickel Crisis of March 2022

Over two trading days ending on March 8, 2022, nickel on the LME rose from below $30,000 a tonne to more than $100,000. Russia's invasion of Ukraine had raised fears for supply from Norilsk, and Tsingshan, the Chinese company that built Indonesia's nickel industry, held a huge short position that it could not cover as margin calls mounted on the exchange's members. The LME suspended trading and cancelled about $3.9 billion of trades executed that morning, a step without precedent in its modern history.

The English courts upheld the cancellation against suits by the hedge fund Elliott and the trading firm Jane Street, the LME introduced daily price limits, and the independent review criticized the exchange's oversight of its members' positions. The episode taught that a benchmark is only as strong as its rules, and that the world's nickel price could be set by one Chinese producer's position. Trading in the contract fell sharply afterward, and Indonesia is now building a venue of its own.

16c. The 2026 Bull Market

The IEA's word for 2025-26 is 'rebounded'. LME copper set records of $14,527.50 in January and $14,875 in September 2026, aluminum reached a four-year high in April, cobalt more than doubled under the Congo's quotas, tungsten rose about fivefold from its 2025 average, silver and tin set records, and the rare earths split into two tiers. The drivers are the ones this course has traced: demand rose from grids, storage, data centers, and defense, mines were disrupted, producers imposed quotas and China licenses, tariffs split markets, and a war closed the Strait of Hormuz.

The market's structure in 2026 is telling. Copper outside the United States was in backwardation, with the spot premium at a five-year high in August, while New York traded hundreds of dollars a tonne above London through the summer and American stocks swelled past an estimated 1 million tonnes. Lithium and cobalt, by contrast, fell sharply in the third quarter as supply responded, a reminder that a bull market in minerals is several markets running on their own clocks.

Analysts who call the rise structural point to a decade of under-investment meeting a decade of policy-driven demand, and the risks they name are a recession, a collapse in Chinese demand, and the substitution that every squeeze produces.

16d. Who Pays for Mines

Source	How	2025-26
The majors' cash flow	Retained earnings reinvested by BHP, Rio Tinto, Glencore, Freeport, and others	High copper prices; spending favors expansions of existing mines
Equity markets	Placements and listings for junior miners on the Toronto, Australian, and London exchanges	Closed to juniors in 2023-25; reopened for rare-earth, antimony, tungsten, and copper names with government support
Debt	Bank project finance, bonds, and government lenders	Commercial banks cautious; EXIM approved $2.9 billion for Perpetua (May 2026)
Streaming and royalties	Wheaton Precious Metals, Franco-Nevada, and Royal Gold pay up front for a share of future output	The financier of mid-sized miners
State capital	Chinese state companies and banks; Gulf funds and Ma'aden; the Pentagon, the Energy Department, EXIM, and the DFC; JOGMEC; Australian and Canadian credits	Public finance commitments quadrupled to $65 billion over 2023-25 (IEA)
Traders and offtakers	Glencore, Trafigura, and Mercuria prepay for output; automakers take stakes and offtakes (GM at Thacker Pass)	Automakers as bankers; traders inside Project Vault
In all		Investment in new supply fell 9% in 2025 (IEA)

Most mining capital comes from the majors' own cash flow, which is why a copper boom produces expansions of existing mines rather than new ones: a board prefers a project with known geology next to an existing pit to a $6 billion bet on a new deposit in a new country. The junior miners who find the deposits could not raise money in 2023-25 and can now mostly do so where a government has signaled support.

The gap has been filled by state capital, Chinese state companies first and Gulf funds and Western governments after them, and by customers, with automakers financing lithium and the Pentagon financing magnets. The IEA's finding that investment fell 9% in 2025, even as prices rebounded, is the conclusion: the price is finally high and the capital is still slow to come, because the policy risk of Module 12 cannot be priced and the timeline of Module 2 cannot be shortened.

Module 16 Key Points

Prices, Markets, and Finance

• Base metals trade on the LME, COMEX, and Shanghai; most critical minerals trade on opaque assessed prices, and rare earths in two tiers.

• On March 8, 2022, LME nickel spiked past $100,000 a tonne, and the exchange cancelled about $3.9 billion of trades.

• Copper set records in 2026, with New York hundreds of dollars above London in summer; lithium and cobalt fell in the third quarter.

• Most mine finance comes from the majors' cash flow, which favors expansions; junior miners depend on government signals.

• Public finance commitments quadrupled to $65 billion over 2023-25, yet investment in new supply fell 9% in 2025.

Module 16 Quiz

Check Your Understanding

1. How have rare earths been priced since 2025?

A) In two tiers, inside and outside China
B) On the LME
C) On COMEX in New York, under a contract launched after the 2025 controls
D) By a World Trade Organization reference price that every member applies

2. What did the LME do on March 8, 2022?

A) Closed for good
B) Raised its margin requirements and let the price run to $200,000 a tonne
C) Cancelled the morning's nickel trades
D) Listed lithium for the first time to calm the market after Russia's invasion

3. Which venue became the most liquid market for lithium?

A) The LME
B) The Guangzhou Futures Exchange
C) COMEX
D) A Fastmarkets assessment published from London each week for European buyers

4. Why does a copper boom produce expansions rather than new mines?

A) Environmental rules forbid new sites in every major producing country
B) China builds all the new mines and sells them to Western companies
C) No new deposits are left to find anywhere in the world's copper belts
D) Majors spend where they already are

5. What does the finance section conclude about 2026?

A) The price is finally high, but capital is slow because policy risk cannot be priced and timelines cannot be shortened
B) Capital is flooding in
C) Prices are too low
D) State capital has withdrawn

Module 17 — Environment, Communities, and the Social License

The Constraints That Stop Mines

Recommended Reading / Reference

Book: Siddharth Kara, *Cobalt Red: How the Blood of the Congo Powers Our Lives* (2023)

Reference: The Global Industry Standard on Tailings Management (2020); the Brumadinho and Mariana settlements; the report of Panama's commission on Cobre Panama (September 30, 2026); the federal courts' 2025-26 rulings on Oak Flat; the OECD's due-diligence guidance for mineral supply chains

Constraint	What it is	Where it bites	Cases	2025-26
Water	Mines and plants use and contaminate water: copper concentrators, brine ponds, acid leaching, seepage from tailings	The Atacama, Nevada, Arizona, the Andes, Indonesia's coasts, the Congo's rivers	Escondida's desalination; limits on Chilean brine; Thacker Pass's water rights; Resolution's aquifer	Water shortages forced some smelters at Indonesia's Morowali park to cut output (September 2026)
Tailings	The waste slurry stored behind dams	Everywhere; the deadliest failures in Brazil and South Africa	Brumadinho (2019; 272 dead; Vale); Mariana (2015; 19 dead; Samarco, owned by Vale and BHP); Jagersfontein (2022); Mount Polley (2014)	The 2020 global standard; Mariana's settlement of about 170 billion reais (October 2024); Indonesia's new leaching tailings the next risk
Indigenous rights and sacred sites	Free, prior, and informed consent; land claims	The US West, Canada, Australia, Latin America, the Nordic countries	Oak Flat (Resolution Copper); Juukan Gorge (Rio Tinto, 2020); Thacker Pass; Sami land in Sweden	The Oak Flat transfer of March 16, 2026, with litigation continuing
Artisanal mining and child labor	Informal digging in the Congo's cobalt belt; children in cobalt, mica, tin, and tantalum	The DRC, Madagascar, Myanmar	*Cobalt Red*; the Dodd-Frank conflict-minerals rule; buyers' audits	The DRC's push to formalize; quotas that fall on informal miners
Local opposition and permitting	Communities, environmental groups, and courts that block or delay projects	The US (Pebble, Twin Metals), Europe (Jadar in Serbia; Portugal's lithium), Latin America (Cobre Panama; Peru's Las Bambas)	Pebble's 2023 veto by the Environmental Protection Agency (EPA); Cobre Panama shut since November 2023; protests at Jadar	Panama's commission: restart only to pay for closure (September 30, 2026)
Carbon and energy	Processing follows cheap power, often coal	China's coal-powered chain; Indonesia's captive coal plants	The EU's carbon border adjustment mechanism (CBAM) on aluminum and steel imports	CBAM's first year of charges, 2026
Capital and investors' screens	Investors' environmental, social, and governance (ESG) screens on mining	Western capital markets	The 2020-23 push; the 2024-26 retreat as governments put supply first	Security, not sustainability, is now the frame

17a. Water and Tailings

Mining's environmental constraints are water and waste. Copper mines and lithium brine operations sit in deserts, the Atacama, Nevada, and Arizona, where water is contested by farms, cities, and indigenous communities, which is why Escondida desalinates seawater, Chile has limited brine extraction, and Thacker Pass's water rights were litigated for years. In September 2026 water shortages forced some nickel smelters at Indonesia's Morowali industrial park to cut output.

Tailings, the slurry of crushed rock and chemicals left after the metal is removed, are stored behind thousands of dams and are the industry's deadliest liability. Vale's dam at Brumadinho in Brazil collapsed in January 2019 and killed 272 people, and Vale agreed in 2021 to pay 37.7 billion reais, about $7 billion. The Mariana collapse of 2015 poisoned a river system and ended in a settlement of about 170 billion reais, about $30 billion, in October 2024. The global tailings standard of 2020 is now being tested by the leaching tailings of Indonesia's nickel industry, built fast on coasts in a seismic zone.

17b. Communities and Consent

The mines that do not get built are usually stopped by people rather than geology. Resolution Copper in Arizona, which its owners say could yield about 18 million tonnes of copper, was held up for more than a decade by the San Carlos Apache's claim to Oak Flat, a sacred site that the mine would turn into a crater. The Supreme Court declined to hear the case in 2025, and the land passed to the company on March 16, 2026, after an appeals court refused to block the transfer, with litigation continuing.

Rio Tinto's destruction of the 46,000-year-old rock shelters at Juukan Gorge in 2020 cost its chief executive his job and led Western Australia to rewrite its heritage law. Panama's Cobre Panama, about 1.5% of world copper and about 5% of Panama's economy, was closed by the country's Supreme Court in November 2023 after national protests. On September 30, 2026 a government commission recommended a restart only to pay for an orderly closure, and estimated that closing without a deal would cost $2.6-3.4 billion over 17-19 years.

Serbia's Jadar lithium project, Europe's largest, was approved, revoked, re-approved, and stalled by protests. The Congo's artisanal cobalt diggers, children among them, documented in Siddharth Kara's *Cobalt Red*, are why cobalt carries a reputational premium and why the Congo's quotas fall hardest on the informal miners they do not count. Free, prior, and informed consent is the standard in law and treaty across much of the Americas, Australia, and the Nordic countries, and it is where the eighteen-year timeline of Module 2 is made.

17c. Faster Permits or Consent: The Argument

The case for speed. The administration, much of Congress, and the industry argue that permitting delay is a national-security risk, because nearly eighteen years from discovery to production cannot answer a Chinese export ban that works in weeks. Western mines held to higher standards than Chinese or Congolese ones push production to places with worse records. They point to the March 2025 executive order, the FAST-41 priority list, the Oak Flat transfer, and the House's Critical Mineral Dominance Act, passed 224-195, and to the European Union's own limit of 27 months for permitting strategic mining projects.

The case for consent. Tribes, environmental groups, and many local governments argue that consent is not a delay but the condition of a durable mine. Projects that skip it lose more time than they save, as Cobre

Panama shows: Panama's commission puts the cost of its closure at $6.85 million of export earnings a day. Tailings failures like Brumadinho show what weak oversight costs, and a security frame that loosens investors' screens shifts risk onto communities that did not choose it.

The evidence. Faster paper has not yet meant faster mines. Resolution has its land after thirteen years but still faces litigation and years of construction, and Thacker Pass, approved in 2021 and upheld by the courts in 2023, will produce in late 2027 at the earliest. Meanwhile the projects that lost their social license, Cobre Panama and Jadar, are the largest losses of Western-aligned supply of the decade.

The course's reading. Speed and consent are not opposites in practice, because the permits that hold are the ones communities accept, and the security frame has changed who wins the fights more than how long they take. Water, tailings, and land still decide whether a mine is built.

Module 17 Key Points

Environment, Communities, and the Social License

• Water and tailings are mining's environmental constraints; Brumadinho's 2019 dam collapse killed 272 people.

• Most mines that are never built are stopped by people: Oak Flat took thirteen years, and Cobre Panama has been shut since 2023.

• Panama's commission recommended in September 2026 that Cobre Panama restart only to pay for its own closure.

• Advocates of speed call permitting delay a security risk; advocates of consent call consent the condition of a durable mine.

• Faster paper has not yet meant faster mines; the permits that hold are the ones communities accept.

Module 17 Quiz

Check Your Understanding

1. What is mining's deadliest liability?

A) Diesel fumes
B) Air pollution from smelter stacks, which kills more people each year than any dam failure
C) Tailings dam failures
D) Water use in the deserts where most copper and lithium mines sit

2. Why was Resolution Copper held up for more than a decade?

A) An Apache claim to Oak Flat, a sacred site
B) A lack of ore
C) Chinese competition
D) A water shortage that the state of Arizona declared when its aquifers fell in 2013

3. What did Panama's government commission recommend on September 30, 2026?

A) A full restart under a new 40-year concession with First Quantum and a larger royalty
B) Nationalizing the mine and selling it to a Chinese state company to pay the arbitration awards
C) Keeping the mine closed for good, with no processing of the stockpiles already on site
D) A restart only to fund closure

4. What is the case for consent, as its advocates make it?

A) Mining should be banned
B) Consent is the condition of a durable mine, and projects that skip it lose more time than they save
C) Permits should take 27 months
D) Security matters most

5. What does the module conclude about faster permits?

A) They have doubled output
B) They have ended litigation
C) Faster paper has not yet meant faster mines: litigation and construction still take years
D) They are unconstitutional

Module 18 — Where Things Stand, and What to Watch

The Argument, the Turning Points, and the Dates

Recommended Reading / Reference

Reference: IEA, *Global Critical Minerals Outlook 2026*; USGS, *Mineral Commodity Summaries 2026*; China's Ministry of Commerce announcements of November 2025; the International Copper Study Group's forecasts; Benchmark Mineral Intelligence's quarterly price reviews; the companies' and agencies' published schedules

18a. The Argument

The critical-minerals economy of October 2026 is a network of managed channels. China controls licenses, allocation, and enforcement across a dozen materials and can calibrate each buyer's access, while the Congo and Indonesia use quotas and export rules to demand processing and revenue, and Zimbabwe, Guinea, and Chile follow. The United States answers with floors, stakes, loans, purchases, export restrictions, and reserves, Japan stockpiles, Europe sets targets and now funds some of them, and the Global South sells access to the highest bidder.

Prices in the managed channels are policy prices: the Pentagon's $110 floor against NdPr near $109 in China and $107 outside it, cobalt set by a Congolese quota, nickel by an Indonesian permit, and dysprosium at 16 times China's price for buyers outside China. The exchange prices that remain, for copper and aluminum, are being split by tariffs into regional tiers and shaken by a war. The risk the analysts name is not that governments fail to act but that they act in the wrong order.

18b. Six Turning Points, One Lesson

Six turning points, each taught in its home module, carry one lesson. China's 2010 cutoff of Japan showed that a supplier's share is a weapon, and Japan alone drew the lesson. The LME's 2022 nickel crisis showed that a benchmark is only as strong as its rules, and that one Chinese position could set a world price, and the Congo's 2025 cobalt quota showed that a producer with an irreplaceable share can double a price by decree.

The April 2025 rare-earth halt showed that dependence works in weeks while alternatives take years. The Pentagon's 2025 deal with MP Materials showed that the answer to a policy price is a policy price, and Simandou's first ore in November 2025 showed that the buyer with capital and patience gets the mountain. Every turning point was about control rather than geology, and the West, having spent a decade of warnings on other things, is building at the pace of the eighteen-year mine against an adversary that built at the pace of policy.

18c. Five Contradictions

- **The floor and the market:** the $110 floor was meant to free a Western producer from Chinese pricing, yet Chinese pricing sets its cost: it paid MP $59.9 million in the first half of 2026 because the market price, set in China, stayed below $110.

• **The quota and the substitute:** the Congo's quota more than doubled cobalt's price, and every dollar of the rise advertised the cobalt-free cells that will shrink the market it controls.

• **The surplus and the shortage:** the copper study group forecasts surpluses for 2026-27 while the banks forecast deficits, and both are right about different warehouses.

• **The stockpile and the refinery:** Washington is buying reserves of materials it cannot yet process, while the Pentagon cancelled its own lithium tender.

• **Speed and consent:** permits have been accelerated, yet the largest losses of supply came from mines that lost the consent of their communities.

18d. The Watch List

What	When	Why it matters
The US midterm elections	November 3, 2026	Affordability and tariffs, including the undecided duty on refined copper
China's suspension of its ban on gallium, germanium, and antimony exports to the US reaches its end date, which the truce's extension did not mention	November 27, 2026	Whether the minor metals' reprieve moves with the truce or lapses on its own
MP Materials' first commercial magnets from its larger Texas plant	Late 2026	Whether a non-Chinese magnet chain delivers at scale
EXIM's authorization expires; Project Vault's purchase rules	December 31, 2026	Whether the reserve keeps its financing
Indonesia's mineral exchange; Zimbabwe's ban on lithium concentrate exports; US defense rules against Chinese tungsten	January 2027	Three rules due at the turn of the year
The extended truce ends, and with it China's suspension of its October 2025 controls on rare earths, graphite anodes, and battery technology	January 10, 2027	Another extension, selective renewal, or reimposition: the largest single event for magnets and anodes
A decision on a US tariff on refined copper	Pending; 15% from January 2027 was studied	Whether metal keeps flowing into American warehouses
A NOAA permit for The Metals Company	Possibly early 2027	The first commercial seabed mining under US law
EGA's Al Taweelah smelter back to pre-war output	Early 2027	The return of Gulf aluminum
The Congo's cobalt quota and concentrate waivers in practice	2027	The doctrine's next step
Iluka's Eneabba refinery	2027	Heavy rare earths from Australia
The US restriction on exports of tungsten scrap and black mass lapses unless renewed	Late August 2027	Whether a one-year measure becomes permanent
Grasberg near full capacity; Thacker Pass's first production	End of 2027	The largest swing in copper supply; the first large new American lithium mine in decades
Perpetua's antimony; USA Rare Earth's Round Top; NioCorp's scandium	2028	The minor-metal base
China's share of rare-earth refining	2035	About 70% in the IEA's projection, if planned plants are built

18e. The Last Word

The throughline of these eighteen modules is that the modern economy is made of a few dozen materials that are mined in many places and refined in one, and that the country which refines them learned in 2025 that it could stop the world's production lines in weeks. The West's response, with floors, stakes, offtakes, reserves, allied deals, and export controls of its own, is the producers' doctrine in mirror image. It will produce a partial supply base for the light rare earths and lithium by the end of the decade, and not, before the mid-2030s, for the elements its weapons need most.

The producers of the Global South have discovered that a critical mineral is leverage, and they are using it, while the demand side has discovered that substitution is the fastest escape. What 2025 and 2026 settled is that critical minerals are no longer a commodity market with a geopolitical footnote but a geopolitical contest with a commodity market attached. The calendar of that contest, from the truce's deadlines through the 2027 deliveries to the refineries of the 2030s, is now a calendar every industry that depends on them has to keep.

Module 18 Key Points

Where Things Stand, and What to Watch

• Critical minerals now move through managed channels: Chinese licenses, Congolese and Indonesian quotas, and American floors and stakes.

• Six turning points from 2010 to 2025 carry one lesson: control, not geology, sets supply and price.

• The $110 floor's cost is set by Chinese pricing: it paid MP $59.9 million in the first half of 2026.

• Watch November 27, 2026 for the minor metals and January 10, 2027 for the extended truce, beside three rules due in January.

• The light rare earths and lithium can be diversified by 2030; the heavy elements and magnets stay Chinese into the 2030s.

Module 18 Quiz

Check Your Understanding

1. What has replaced the market in critical minerals, according to the closing module?

A) Free trade
B) A producers' cartel modeled on OPEC with a secretariat in Kinshasa
C) A United Nations minerals regime that assigns quotas to each producing country
D) A network of managed channels

2. What lesson do the six turning points share?

A) That markets always correct themselves once prices rise high enough to draw supply
B) Control, not geology
C) That geology decides everything, since deposits cannot be moved or replaced
D) That stockpiles end every squeeze within a year of its start

3. Why does the module count the $110 floor among its contradictions?

A) It was meant to free a producer from Chinese pricing, yet Chinese pricing sets its cost
B) Congress repealed it in 2026
C) China matched it with a floor of its own
D) It was set so low that MP never collected anything under it, even in 2026, when prices outside China were highest

4. What ends on January 10, 2027, unless it is extended again?

A) The Congo's cobalt quota
B) EXIM's authorization
C) Zimbabwe's lithium quotas
D) The extended US-China truce, and with it China's suspension of its October 2025 controls

5. Which dependence does the course expect to last into the 2030s?

A) Lithium
B) Heavy rare earths and magnets
C) Iron ore
D) Copper, because no new mine anywhere in the world will be approved before 2035 under current rules

Answer Sheet

Answers to every module's Check Your Understanding quiz.

Module	Answers
Module 1 Quiz	1. A 2. B 3. D 4. C 5. B
Module 2 Quiz	1. C 2. D 3. A 4. B 5. A
Module 3 Quiz	1. C 2. D 3. A 4. D 5. C
Module 4 Quiz	1. B 2. B 3. A 4. C 5. D
Module 5 Quiz	1. C 2. D 3. A 4. B 5. D
Module 6 Quiz	1. A 2. C 3. B 4. B 5. A
Module 7 Quiz	1. C 2. D 3. B 4. C 5. D
Module 8 Quiz	1. A 2. A 3. D 4. B 5. C
Module 9 Quiz	1. D 2. A 3. C 4. B 5. C
Module 10 Quiz	1. B 2. A 3. D 4. C 5. A
Module 11 Quiz	1. B 2. D 3. A 4. B 5. C
Module 12 Quiz	1. D 2. C 3. D 4. B 5. A
Module 13 Quiz	1. A 2. D 3. C 4. B 5. D
Module 14 Quiz	1. B 2. C 3. A 4. C 5. B
Module 15 Quiz	1. D 2. A 3. C 4. D 5. B
Module 16 Quiz	1. A 2. C 3. B 4. D 5. A
Module 17 Quiz	1. C 2. A 3. D 4. B 5. C
Module 18 Quiz	1. D 2. B 3. A 4. D 5. B