



GLOBAL BUSINESS REPORTS

WESTERN USA MINING 2024-25



Pre-Release Edition

Image courtesy of Rio Tinto Kennecott



Changing Tides

Navigating the waters of a domestically produced energy transition

In 2023, the United States achieved a record high for mineral imports, marking an all-time low for supply chain stability. According to the US Geological Survey's (USGS) 2023 Minerals Commodity Summaries report, the US was more than 50% reliant on 51 minerals. The US is also 100% net import reliant for 15 of those 51 minerals, 12 of which are deemed "critical" according to the USGS' 2022 Final List of Critical Minerals. In 2024, not much has changed. The US is more than 50% reliant on 49 minerals and 100% reliant on the same 15. For the country to achieve a secure green energy transition, it is critical to ensure a supply of domestically produced material.

The US government pledged net zero carbon emissions by 2050 and that 50% of vehicles sold by 2030 will be electric. To reach carbon neutrality, 90% of electricity must be generated by renewable technologies. It is estimated that 384 mines must be built by 2035 to meet EV and energy storage battery demand alone, according to Benchmark Intelligence. This does not factor in the materials needed for solar panels, wind turbines, or electrical infrastructure. The outlook is bleak: the share of fossil fuels in global energy use decreased only 4% from 1997 to 2022, according to Vaclav Smil's "Halfway Between Kyoto and 2050" report. Though not impossible, to achieve net-zero, affluent countries like the US will incur minimum costs of 20% of annual GDP. Based on 2023's GDP, that would be equivalent to US\$5.47 trillion. However, mining of metals and minerals contributed US\$185 billion to the country's GDP in 2023, according to the USGS's 2024 Minerals Commodity Summaries report.

The government's aggressive plans to advance the green energy transition lacks the backing of domestically produced raw material. The US is import reliant for the entire battery supply chain, and for the materials needed to produce renewable energy and storage technologies. Geopolitical tensions could sever the US's hopes for a cleaner future at the swing of a pickaxe. "It is in our best interest to figure out how to utilize our country's own resources so that we do not put ourselves in a position where others can dictate what we have access to," said Tawana Bain, CEO of American Clean Resources Group, a firm turning to tailings to help the US gain self-sufficiency.

"Addressing climate change and transitioning to sustainable energy are issues beyond a single balance sheet. We will need more partnerships in mining for the next 20 years than the past century."

Nathan Foster,
Managing Director
Kennecott,
Rio Tinto



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Copper, one of the leading metals for the transition, may not shine as bright as gold, but is equally the United States' plunder. Lately, the metal has been treated as fool's gold. Import reliance for copper grew 5% from 2023 to 2024. This reliance will only increase as American demand for copper will far outstrip supply in the coming years. Currently the US is lacking both raw and refined supply, housing only two functional smelters. Despite its critical role in the green energy transition and being 46% import reliant on the metal, copper is not defined as a critical mineral by the US government. The USGS even denied a bipartisan request to add copper to the list.

Nevada: a lithium island

Capital markets have been hesitant to invest in the lithium space, given the commodity's poor performance over the past 12 months. The US government has been especially involved in this space. While capital markets require quick returns, the US government is looking longer term, seeing lithium through the lens of green energy transition demand.

Given its geology, Nevada has emerged as the leader in the lithium space. Processing capabilities, however, are lagging. "Nevada is one of the few places on the planet with large enough critical element deposits to support multigenerational activity in mining, extraction, and advanced manufacturing. However, there is a large gap in processing abilities. Nevada is currently a net exporter of raw critical element ore to China," explained Frederick Steinmann, director, University Center for Economic Development, University of Nevada, Reno (UNR).

In 2023, the UNR received US\$1 million in financing from the NSF's Regional Innovation Engines program. "We recognize the processing and refining gaps and are attempting to bring in new technologies and improve old ones. We are working with consultancies and venture capital firms to provide information, knowledge, sophistication, and support to move towards commercialization," highlighted Erica Hall, senior project manager at UNR.

The Biden-Harris administration declared goals of ensuring 50% of vehicle sales will be electric by 2030. Nevada received four federal investments as the US aims to increase market share in the battery space. Under the Bipartisan Infrastructure Law, the DOE awarded a sum of US\$4.62 billion to 35 projects in 2022 and 2023. Three are in Nevada.

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Recycling: Opening a new treasure chest

At 29 years, the lead time to bring a mine into production in the US is second only to Zambia. This timeline immediately extinguishes any hopes of a domestically sourced green energy transition. Recycling firms are surfacing to provide an alternative.

There is an estimated 280 billion t of inactive tailings deposits worldwide, estimated to contain trillions in estimated value of precious, critical and strategic metals. Reprocessing this material is a no-brainer according to Bain of American Clean Resources Group: "The reintroduction of minerals and metals that were once considered waste into the supply chain not only diversifies our sources of supply but also advances America's goal of self-reliance. This shift has the potential to transform the mining industry in the United States, creating safer job opportunities and redefining the sector's future.

The firm is starting with the tailings contained in the 1,183 acres of their Tonopah property in Nevada.

In parallel, ABTC and Redwood materials are recycling batteries in Nevada. With its lithium extraction and battery recycling, ABTC created a loop: "A closed-loop supply chain differs from the traditional hydrocarbon economy, where resources are used once and depleted. For elements like lithium, having strong partnerships, with refiners, manufacturers, OEMs and others allows us to maintain control over these materials indefinitely," said Ryan Melsert, CEO and CTO, American Battery Technology Company.

Solar panels are providing another type of recycling feedstock, "100,000 t of waste solar panels are generated annually, mostly

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"Educational initiatives in Colorado, like the Colorado School of Mines' and Colorado State University's, are fostering a proactive approach to the development of much needed human resources for the mining sector."

Jeffrey Coffin,
COO,
Knight Piésold USA



from California, Arizona, and Nevada. By 2030, this is expected to rise to 1 million t," said Corrado De Gasperis, executive chairman and CEO, Comstock Inc.

In 2023, Comstock Metals, a subsidiary of Comstock Inc., established a commercial demonstration facility. "We are proving that we can economically recycle 100% of end-of-life solar panels. These materials include glass, silica, aluminum, copper, and a high-silver-content metallurgical ore," added De Gasperis.

Walk the plank

There is one critical resource where the shortage is due to limited deposits, not regulations: talent. 71% of mining leaders say the talent shortage keeps them from delivering on production targets, according to McKinsey, exacerbating the supply problem further.

While the mining industry will consistently add between 11,000 and 13,000 jobs annually for the next 20 years, the number of people entering the workforce dwindles. In April 2023, the US mining sector had 36,000 job vacancies, up from 27,000 in 2022. US mining graduates declined by 39%, with only 600 mining engineering students across the US in 2022, a sharp decrease from 1,500 in 2015. The University of Arizona, representing approximately 10% of mining engineering undergraduate students, typically maintains an undergraduate class size of about 60 students. This, however, has become increasingly difficult. "The latest data indicates that the university has maintained steady enrollment in our mining engineering program at a time when enrollment figures nationally have declined 30%," noted Jodi Banta, program manager and workforce development researcher at the University of Arizona School of Mining and Mineral Resources.

A substantial portion of the decline is indebted to a lack of visibility. Banta emphasized: "A major challenge in recruiting talent for the mining industry is its low visibility, making it less attractive compared to more well-known fields. Many students lack familiarity with mining and struggle to envision a career in it."

This shortage presents an imminent challenge. According to the Society for Mining, Metallurgy, and Exploration (SME), around 220,000 US mining workers are expected to retire by 2029. This mass exodus will leave a significant knowledge and skill gap that must be addressed, particularly as the demand for critical minerals such as lithium, cobalt, and rare earths continues to grow.

The talent shortage affects the entire mining value chain from exploration to engineering, operations, and sustainability roles. According to the International Council on Mining and Metals (ICMM), the global shift toward automation and digitalization

requires highly specialized skills, further compounding the talent gap. New roles, such as data scientists, geospatial analysts, and artificial intelligence (AI) specialists, are becoming increasingly vital. "The mining industry is currently contending with significant macro trends that hinder effective data utilization, most notably the shortage of skilled talent such as mining engineers and geologists," noted Rob Hardman, president and general manager for North America at Maptek.

In September 2023, the Senate Committee on Energy and Natural Resources introduced the Mining Schools Act of 2023, a bipartisan legislation allocating US\$10 million per year, from 2024 to 2031, to a grant program for mining schools in an effort to recruit more students.

A solution to the root of the problem must start early in the education system. "Research revealed a critical lack of awareness about mining careers, highlighted by a survey showing that 60% of American science teachers felt unqualified to recommend mining. To combat this, SMMR launched a mining and minerals teachers' academy for high school and middle school science teachers. This is in addition to our well established K-12 education outreach program, which reaches over 6,000 students and hundreds of teachers annually," shared Banta.

However, technology can help to fill the expanding void. "This year, we are on track to receive over 20,000 employment applications, a significant increase from last year's 11,000," started Keaton Turner, founder, president and CEO at Turner Mining Group. "This surge reflects our robust social media efforts to not only

"Industry and academia need to collaborate to raise mining's profile, emphasizing its role in green energy and national security. Outreach programs and partnerships with local economic development organizations can help improve visibility."

Jodi Banta, Program
Manager & Researcher,
School of Mining &
Mineral Resources,
University of Arizona



promote our brand but also highlight opportunities within the mining sector, particularly in the US," he continued.

The US must urgently prioritize self-sufficiency in critical minerals by increasing domestic production, driving innovation in recycling, and bridging the growing talent gap. These steps are crucial for establishing the nation's leadership in the global green energy transition and ensuring economic and strategic stability. The time to act is now, before external dependencies turn the tide against American energy independence. With the moon full, it is not a question of if the tide will change, but when—and the US must be prepared to rise with the tide. ■

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Production and Development

The green transition catalyzes industry-wide change

The primary demand story driving mineral and metal prices is the world's transition to the green energy economy. Electric vehicles (EVs), photovoltaic cells, wind turbines, energy infrastructure, etc. all require an inexhaustive list of minerals and metals. Within this, EVs receive the most attention. In 2023, nearly one in every five cars sold was electric, and the number of EVs sold globally in the first three months of 2024 was roughly equivalent to the total number sold in 2020, according to the International Energy Agency. "An EV contains four times more copper than an internal combustion engine vehicle. Charging an EV significantly increases a home's peak electricity consumption, comparable to adding 46 refrigerators. The federal goal of converting half of US households to EVs in the next decade will require substantial increases in electricity generation and infrastructure," said Nathan Foster, managing director Kennecott, Rio Tinto.

Humanity's second copper age

For typical commodities, high prices result in reduced demand new supply. Copper is not typical—the exorbitant demand for the metal makes it difficult to reduce demand sufficiently, and the supply side cannot keep up. While copper's last cycle was driven by demand from China, this cycle is primarily driven by lack of supply. Recent supply disruptions—Cobre Panama coming offline, lower than anticipated production output in Chile, and global reduction in ore grades to name a few—triggered the metal's bull run, leading to its record highs. Of the world's 20 largest copper producing mines, only two are in the Western US – Freeport-McMoRan's 72%-owned Morenci, responsible for 2.6% of world supply, and Rio Tinto's Bingham Canyon, responsible for 1.4% of world supply. However, global tensions have turned the spotlight back onto domestic assets. "As global competition for resources intensifies, prioritizing domestic production and reducing dependence on foreign trade will become increasingly important over the next few decades," emphasized Foster.

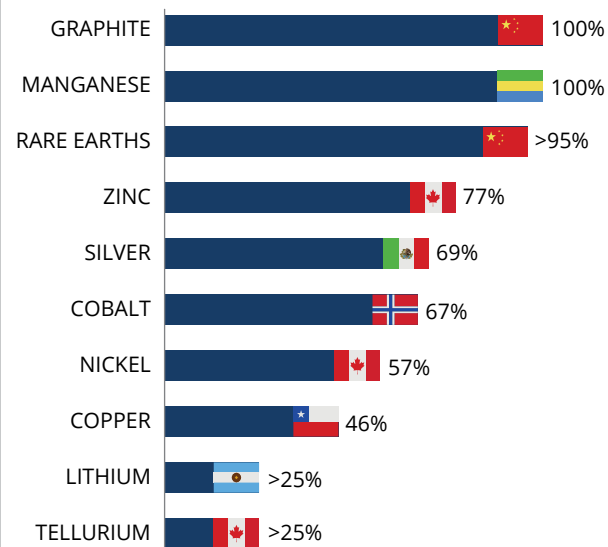
In 2023, domestic mined copper output in the US declined an estimated 11% from 2022. Output reached 1.1 million t/y, a five-year low. Of the 25 mines that produce copper in the US, 17 account for 99% of mine production. The drop in mined copper output can be attributed in part to disruptions at these mines. Copper production across Freeport-McMoRan's North American assets dropped 74 million lb for the first six months of 2024, compared to the same period in 2023, due to lower ore

"There has been no manganese ore mining in the United States since the 1970s, and the US is now 100% reliant on foreign sources for manganese. The Hermosa project can help fill that void."

Pat Risner,
President Hermosa Project, South32



America's Import Reliance for Minerals



The flags represent the countries U.S. depends on the most for each mineral.

Source: Mineral Commodity Summaries 2024, U.S. Geological Survey

"Maintaining domestic supply through operational smelters is crucial for US resilience in copper production. We aim to strengthen these efforts by ensuring consistent supply to meet American demand."

Vicky Peacey, President and General Manager, Resolution Copper



grades and planned mill maintenance. Record-high snowfall and a conveyor belt failure affected production at the Bingham Canyon mine—commonly referred to as Kennecott—in Salt Lake City, Utah. Ramp up at Nevada Copper's Pumpkin Hollow mine was delayed; operations started in October 2023. The company, however, declared bankruptcy in June 2024, halting operations entirely, taking another domestic copper supplier off the table.

2024 started on the right foot. Domestic mines produced 209,000 t in January and February, an 8.29% increase over 2023's 193,000 t for that same period. Production at Kennecott for Q2 2024 was up 30% from the same period last year. First production from the Lower Commercial Skarn, a small underground ore body area was achieved in June 2024, marking the mine's return to underground production after four decades and paving the way for first ore from North Rim Skarn (NRS) by Q1 2025. "In 2023, Rio Tinto invested US\$498 million to begin developing the NRS ore body. The NRS has updated Indicated Mineral Resources of 10.8 Mt at 2.93 % copper, 1.20 g/t gold, 65.97 g/t silver, 0.008 % molybdenum," detailed Foster.

Freeport conducted technical and economic studies in 2023 for a potential expansion project at the Bagdad concentrator to increase copper production by 200 to 250 million lb/y, more than double current production rates. The firm is also working on projects at the Safford/Lone Star operation to increase copper production to 300 million lb/y.

Increased copper production will not necessarily bring the states to where they need to be. Smelting and refining capacity has become the bottleneck, said Paul Harbidge, president and CEO at Faraday Copper: "In the 1970s and 1980s, the Western world shifted away from heavy industry, relocating much of it to China. China built several smelters and now nearly control the production of metals like copper."

The entire US has only two operational smelters: Rio Tinto's Kennecott and Freeport-McMoRan's Miami. However, Grupo Mexico-owned Asarco has plans to restart operations at its Hayden complex in Arizona and Amarillo refinery in Texas. Currently, concentrates from the miner's Mission and Ray mines are sold to China and Japan, however, said Óscar González Rocha, CEO at Asarco, "once the smelter reopens, we would produce a more finished product, the anode, which would be sent to the Amarillo refinery in Texas to manufacture wire rods. This wire rod would be sold primarily on the East Coast of the US."

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"The Hayden concentrator and smelter will remain inactive while we determine how to resume operations. Once online, the Amarillo refinery in Texas will also restart, supplying wire rod to the entire East Coast of the US."

Óscar González Rocha,
CEO, Asarco



"2023 saw 415 gigawatts of new photovoltaic installations globally; this could exceed 1 terawatt annually by 2030. Each gigawatt requires 500,000 oz of silver, resulting in more demand for silver than total global annual supply."

Mitchell Krebs,
President and CEO,
Coeur Mining



Copper development

There are some copper projects with the potential to come online in time to help meet fill the copper supply gap. However, despite the government's outward commitment to the green energy transition, many fear its lack of clear direction when it comes to actually bringing new supply online might act as a major impediment. "Despite quotas on EV sales, the government lacks a clear policy for the clean energy transition. It fails to support mining permitting and infrastructure," emphasized Harbidge.

This narrative may shift, as the government becomes cognizant of the dire need to increase production. "Typically, a company like World Copper would focus on exploration and development

to expand a deposit. However, given the current deficit and our asset's potential to quickly impact production, we decided to move straight into production. The US Government is actively supporting us in this endeavor, and we are working closely with them to ensure it happens," said Gordon Neal, the firm's president and CEO.

At Resolution Copper, the Rio Tinto- BHP joint venture, the Ninth Circuit Court of Appeals denied Apache Stronghold's request to further hear their case to stop the land exchange between Resolution Copper and the federal government. In 2024 the firm signed a Good Neighbor Agreement with surrounding towns, counties and groups. "Over the last decade, we worked closely with local communities to co-design what this mine will look like. The

"With average annual copper cathode production of 116,052 short tons in the first 20 years, our Cactus project ranks fifth in scale in the US, positioning us as a key supplier to the domestic market."

George Ogilvie,
President and CEO,
Arizona Sonoran Copper
Company



project has evolved significantly due to the input from communities and Native American tribes, ensuring we can coexist with nature, riparian areas, and ancestral sites," said Vicky Peacey, president and general manager.

The pipeline is growing. In March 2024, Arizona Sonoran acquired the 523-acre MainSpring property immediately adjacent to its Cactus project, enabling the firm to factor the now combined Parks/Salyer deposit with MainSpring into a mineral resource estimate. There was a 1,904% increase to the Measured Category at Parks/Salyer, 26% increase to the total M&I and a 60% increase in total Inferred resource. "MainSpring brings an additional 1.9 billion pounds (all inferred) of copper to the project. A significant amount of mineralization is close to the surface which allows for open pit mining," said George Ogilvie, President and CEO of Arizona Sonoran.

Lithium production and development

Lithium took the spotlight in 2022 as the EV craze hypnotized Americans, but the mineral's price plummeted 80% over 2023. Compared to copper, the lithium market is immature and high prices lead to demand destruction and new supply. With confusing futures pricing, market leader China made the market opaque, leaving it unclear what a realistic global reference point should be. Despite this, demand grows. US demand alone is predicted to increase 29% year-on-year through 2030, according to Fastmarkets data.

Global lithium supply is predicted to more than double by 2026. However, if prices remain low, this supply is unlikely to become available. US-based Albemarle held numerous spodumene concentrate and lithium carbonate auctions in 2024 to boost market transparency. The firm owns the longstanding sole producing lithium mine in the Western US— the Silver Peak mine in Nevada, where lithium is produced from brine.

Fortunately, 2024 brought with it a new lithium supplier in the US: American Battery Technology Company (ABTC). "In 2021, we were awarded a US\$4.5 million Department of Energy (DoE) grant to build an integrated pilot facility to process claystone from our property into battery-grade lithium hydroxide. We completed the pilot plant in 2024 and recently began producing battery-grade lithium hydroxide" said Ryan Melsert, ABTC's CEO and CTO.

The plant will be supplied by the company's 21-million-ton LCE resource. With a US\$115 million DoE grant, the firm is working to build a commercial-scale refinery with a 30,000 t/y capacity.

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(Cactus Preliminary Economic Assessment - PR Aug 7, 2024)

PEA Highlights:

- NPV8 US\$2,032 million (after tax)
- IRR 24% (after tax)
- Payback Period 4.9 years
- Free Cash Flow (unlevered) US\$7,295 million
- AISC US\$2.00 / lb*
- Initial Capex US\$668 million
- US\$3.90/ lb of Copper

*Includes sustaining, growth, operating capital.

The PEA is preliminary in nature and it includes inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. There is no certainty that the project described in the PEA will be realized. Mineral resources that are not mineral reserves do not have demonstrated economic viability. See ASCU Press Release dated August 7, 2024 for additional information.

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"Less than 1% of global cathode production capacity is currently in North America. The four planned cathode plants will consume more lithium than all the proposed lithium refineries in the USA."

Ryan Melsert,
CEO and CTO,
American Battery
Technology Company



Another player in the Silver State is only a few years behind, with production scheduled for 2027. Australian-based Loneer expects a record of decision on their EIA in October and FID by year-end 2024 on their 350 million ton contained ore lithium and boron project. "Our initial Phase One project is expected to produce about 22,000 t/y of lithium. This deposit can potentially supply enough lithium to power more than 50 million electric vehicles, assuming current efficiency levels", said Bernard Rowe, managing director.

Precious metals production

Silver cannot be overlooked in the green energy transition. Demand is expected to increase 170% by 2030, mainly due to solar

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"Past efforts to compete in the critical minerals space against China have been unsuccessful. Our solution involves creating a new supply chain using byproduct monazite and our Utah facility to produce rare earth materials."

Curtis Moore,
SVP - Marketing &
Corporate Development,
Energy Fuels



panel demand. "2023 saw nearly 500 gigawatts of new photovoltaic installations globally, and experts predict this could exceed a billion gigawatts every year by 2030. Each gigawatt requires nearly 500,000 oz of silver, which could result in more demand for silver than total global annual supply," said Mitchell Krebs, president and CEO of Coeur Mining.

2024's completed expansion of the Rochester mine will help Coeur Mining fill the world's supply gap. "We expect double digit increases for silver, primarily due to Rochester's expansion. For 2024, silver production is projected to be between 10.7 million-13.3 million oz," he highlighted.

Despite having limited industrial applications in the green transition, gold is likely to maintain a positive narrative. As climate change raises global economic uncertainty, gold's traditional role as a safe-haven asset will likely surface, providing source of financial certainty.

Critical Minerals Development and Production

Manganese and rare earth elements are key components of EV batteries. Zinc creates protective coatings for solar panels and wind turbines. For perspective, a 100 MWh solar panel park requires 240 tons of zinc, according to the World Economic Forum. Both manganese and zinc are used in steel production. Rare earths are used in magnets, which underlie everything that powers modern technology, from electric vehicles and renewable energy systems to advanced medical devices and consumer electronics. The US is 100% import reliant for manganese, 95% for rare earths, and 76% for zinc.

One of a few advanced mining projects in the US, South32's Hermosa project in Arizona was confirmed as the first FAST-41 mining project in May 2023, which will introduce efficiency into the federal permitting process. In 2024, South32's board approved a US\$2.16 billion final investment decision to develop the Hermosa project's zinc deposit. "It has the potential to be one of the world's largest zinc producers. The feasibility study for Hermosa's zinc-lead-silver deposit also showed an expected initial operating life for the mine of approximately 28 years, with potential for further exploration upside," said Pat Risner, president of Hermosa at South32.

With China dominating 95% of rare earth element (REE) production and refining, creative measures are required to reduce the US's import reliance. Energy Fuels saw this as an opportunity: "Past efforts by US, Australian, European, and Canadian companies to compete in the critical minerals space, particularly against China, have been largely unsuccessful. Our solution involves creating a new

supply chain using byproduct monazite and our Utah facility to produce advanced rare earth materials," explained Curtis Moore, SVP of marketing and corporate development.

So far, the effort has been successful. "In 2024, we installed a circuit capable of producing up to 1,000 t/y of neodymium praseodymium oxide (NdPr), enough for a million electric vehicles," Moore added.

Uranium

At the World Climate Action Summit of the 28th Conference of the Parties to the UN Framework Convention on Climate Change (COP28), 20 countries agreed on the Declaration to Triple Nuclear Energy. As the title suggests, the aim is to triple nuclear energy's share of the global electricity matrix by 2050 and this was the first COP document backing nuclear energy. Nuclear energy has the lowest carbon footprint of any electricity source and is the least land intensive, according to the World Economic Forum; a thimble-sized pellet of uranium produces as much energy as almost 3 barrels of oil, more than 350 cubic meters of natural gas and about half a ton of coal. The US aims to capitalize on a domestic nuclear advantage, according to Curtis Moore, senior vice president of marketing and corporate development at Energy Fuels, the firm he forecasts to be the largest domestic producer by 2026: "There is a significant effort to rebuild domestic nuclear fuel capabilities, particularly in uranium conversion and enrichment, indirectly benefiting mining."

In 2023, uranium purchases to fuel domestic nuclear power reactors increased 27% over 2022, according to the US Energy Information Administration. Most uranium was sourced from abroad, with 27% from Canada, 22% from Australia and Kazakhstan each, 12% from Russia and 10% from Uzbekistan. Only 5% was sourced domestically. This, however, will likely increase. In May 2024, the President signed the Prohibiting Russian Uranium Imports Act into law, unlocking US\$2.72 billion in funding to build out the domestic nuclear fuel supply chain.

As the world moves deeper into a new era, the importance of securing a reliable supply of essential energy materials cannot be overstated. While the green energy transition offers unprecedented opportunities, it also underscores the urgent need for strategic investments, innovative solutions, and government support to ensure a sustainable and resilient future. ■

"We need to bring mines online faster to meet domestic mineral needs. Fast-41 expedites the federal permitting process and is making a difference in Arizona. The passage of the Mining Regulatory Clarity Act of 2024 would prove helpful. The U.S. remains import-reliant for many critical minerals. This is a crucial issue."

Steve Trussell,
Executive Director,
Arizona Mining Association



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Image courtesy of American Pacific

Western USA Exploration in 2024

The New Manifest Destiny

Apart from numerous Native American tribes like the Yaqui, Hopi, Ute, and Washoe, mineral explorers were some of the first to settle the Western US. As the country expanded, the West emerged as a vast, uncharted frontier, offering a new horizon for those daring enough to venture into its rugged landscapes. The region became a symbol of possibility—a place where the bold could carve out their fortunes from the untapped riches buried beneath the earth. The allure of the West was about the prospect of discovering gold, silver, and other precious metals that lay hidden in the mountains and valleys, waiting to be unearthed by those with the grit and determination to find them.

In 1890, the Census Bureau declared the Western frontier closed. 134 years later, the Western US has become a new symbol of possibility for explorers: an untapped, mineral rich region with the ability to supply the ever-demanding globe.

The Western US's complex tectonic history, marked by subduction zones, volcanic activity, and crustal stretching, created the perfect conditions for the formation of mineral deposits. Many copper deposits in the West are porphyry copper deposits, formed from hydrothermal fluids related to the cooling of magma deep within the Earth's crust. Over millions of years, these fluids moved through fractures in the rock, depositing copper and other valuable metals like molybdenum and gold as they cooled. The result is vast, low-grade but highly concentrated deposits of copper, such as those found in Arizona's Morenci and Bingham Canyon mines. These deposits are so large and rich in copper that they have sustained mining operations for over a century, making them some of the most important sources of copper in the world.

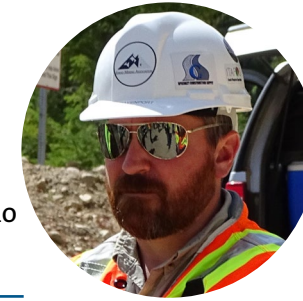
Copper

Porphyry deposits, while typically characterized by evenly distributed mineralization, can exhibit unique geological variations that influence their economic viability. For example, the CuMo deposit in Idaho, a hard rock copper porphyry, presents a distinctive stockwork system. "The nature of our orebody provides significant opportunities to lower CapEx. Unlike typical porphyrys where mineralization is evenly distributed throughout the ore body, our deposit has thin, finger-width veins containing the bulk of the copper, molybdenum, rhenium, and tungsten minerals," said Andrew Brodkey, chief operating officer at Idaho Copper.

A key aspect of these porphyry systems is the presence of breccias—rock formations composed of broken fragments cemented together by a fine-grained matrix. Breccias, formed by intense hydrothermal activity, serve as both hosts and conduits for mineralizing fluids. As these fluids traveled through the fractured rock, they deposited copper and other metals, potentially creating zones of higher-grade mineralization within the broader porphyry system. At Faraday's Copper Creek newly discovered at surface breccia are enhancing the economics of the deposit, said Paul Harbidge, president and CEO at Faraday Copper: "The first new target we drilled, Area 51, has resulted in the discovery of a cluster of breccias exposed at surface with strong copper mineralization. Assay results include: 1.29% copper over 11.36 meters within 45.75 meters at 0.48% copper."

"Although critical minerals lists receive attention, all minerals are vital, as base metals and other non-critical minerals are essential for utilizing critical minerals. The broader need for various minerals, including copper, silver, and gold, remains crucial."

Benjamin Davenport,
Executive Director, Idaho Mining Association



"Arizona is a premier region for copper development. Our deposit consists of a skarn-related porphyry system with significant mineralization in skarn. We have not identified the underlying porphyry, but we have several targets."

Stephen Twyerould,
President and CEO, Excelsior Mining



Lithium

There are two types of lithium deposits in the Western US: brine and clay-rich sedimentary deposits. Clay-rich sedimentary deposits form from the weathering of lithium-rich volcanic rocks. In large volcanic calderas or sedimentary basins, volcanic ash and pyroclastic materials accumulate and alter over time into clay minerals. Lithium, released during weathering or hydrothermal alteration, is incorporated into these clays, with the depositional environment concentrating the lithium through sedimentation and chemical processes. Jindalee Lithium's McDermitt project is hosted in the volcanic caldera, a major benefit according to Ian Rodger, the CEO: "Lithium sedimentary deposits are the copper porphyries of the lithium world—huge, low-grade, generational assets. Our deposit is unique in that it outcrops at the surface, and the rock is very soft, so no blasting or grinding is required. Mining will be very cheap and we expect the waste-to-ore ratio to be around 1."

The shift has been gradual, but remains beneficial in Clayton Valley said Steve Hanson, president and CEO of ACME Lithium: "The region has a history of lithium production since 1966, offering valuable infrastructure like roads, power, and a skilled workforce. The proximity to Albemarle's operation means we are not starting from scratch—there is already community and employment support for lithium production."

Tim Fernback, president and CEO of Grid Battery Metals, agrees: "Nevada's robust infrastructure and emerging lithium resources present excellent opportunities for advancing mining projects and maximizing shareholder returns."

Manifest destiny's legacy

In 1872, the United States government formalized the opportunity to exploit the US's geological riches through the mining law, a piece of legislation that opened the doors to the mineral resources on public lands. Anyone who could find valuable minerals could stake a claim. The mining law reflected the broader spirit of the time, a period when the nation was focused on growth, expansion, and the harnessing of its natural resources. The law is still in effect and "is old and complicated," emphasized Chris Summers, CFO of Burgex Mining Consultants.

Claims are also no longer free, continued Summers: "The basic maintenance fee has gone up from US\$165 to US\$200 per claim, which is significant when multiplied by thousands of claims. We

are already seeing companies not renewing claims due to the fee increase. While the BLM is mandated to review fees every five years, the magnitude of this year's increase is significant. It is disheartening because we need this investment for the US to achieve its goals, particularly for the green energy transition."

This new chapter in exploration history is not just about conquering the land, but about responsibly harnessing its resources to build a more sustainable and self-reliant future for the United States. The stakes are high, but so too is the potential for a new kind of prosperity—one that respects both the land and the legacy of those who first ventured westward. ■

IDAHO COPPER

DEVELOPING A WORLD CLASS COPPER PROJECT IN THE USA

Idaho Copper is advancing the massive CuMo copper-molybdenum-silver project in southern Idaho, near the capital of Boise. CuMo currently has Measured and Indicated Resources of almost 4 billion pounds of copper, 1.6 billion pounds of molybdenum, and 170 million ounces of silver, making it one of the largest undeveloped copper and molybdenum projects in the Americas.

Using innovative techniques such as ore sorting, Idaho Copper intends to publish an updated Preliminary Economic Assessment (PEA) in early 2025 with improved economics and significantly less capital than the results from a PEA released in 2020.

Andrew Brodkey, CEO/COO
abrodkey@idaho-copper.com, 520-850-0274

Robert Scannell, CFO
rscannell@idaho-copper.com, 415-370-9209

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- Jose Latour

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Exploration and Development

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Arizona

"Being on private land, Zonia benefits from easier permitting. It has on-site power, water, and a was pre-stripped, providing a one-to-one strip ratio. We are targeting production within 3-4 years, with the private land resource supporting 70 million lbs/y copper for ten years."



Gordon Neal,
President and CEO,
World Copper

"Metallurgical results show potential to increase throughput from 30,000 t/d to 45,000 t/d by adding a coarser grind size and gold as a payable byproduct. Results confirm sulphide recoveries above 94% and concentrate above 30% copper."



Paul Harbidge,
President and CEO,
Faraday Copper

Nevada

"Rhyolite Ridge contains a boron mineral instead of clay found in sedimentary deposits, a mineralogy not found anywhere else. Rock is crushed to the size of a golf ball before leaching, easing separation of solids from lithium and boron-containing liquid."



Bernard Rowe,
Managing Director,
Ioneer

"Exploration results at Texas Spring yielded average lithium grades of 2,010 ppm and up to 5,610 ppm. Our Volt Canyon project area is underexplored; initial geophysics and soil sampling suggest a larger lithium accumulating structure."



Tim Fernback,
President and CEO,
Grid Battery Metals

Idaho

"2020's PEA revealed a resource of 2.3 billion mineable tons containing 3.8 billion lb of copper, 1.6 billion lb of molybdenum and hundreds of millions of oz of silver, all in M&I."



Andrew Brodkey,
Chief Operating Officer,
Idaho Copper

Oregon

"McDermitt is the largest Lithium resource in the US, containing 21.5 million t LCE. Our deposit outcrops at the surface and the rock is soft, so no blasting or grinding is required."



Ian Rodger,
CEO,
Jindalee Lithium

Alaska

"30% of Whistler's value is copper. We have 1.1 billion lbs copper, (0.7 billion inferred, 0.4 billion indicated). We have 2 million oz of indicated and 4.7 million oz inferred gold. Silver is also present."



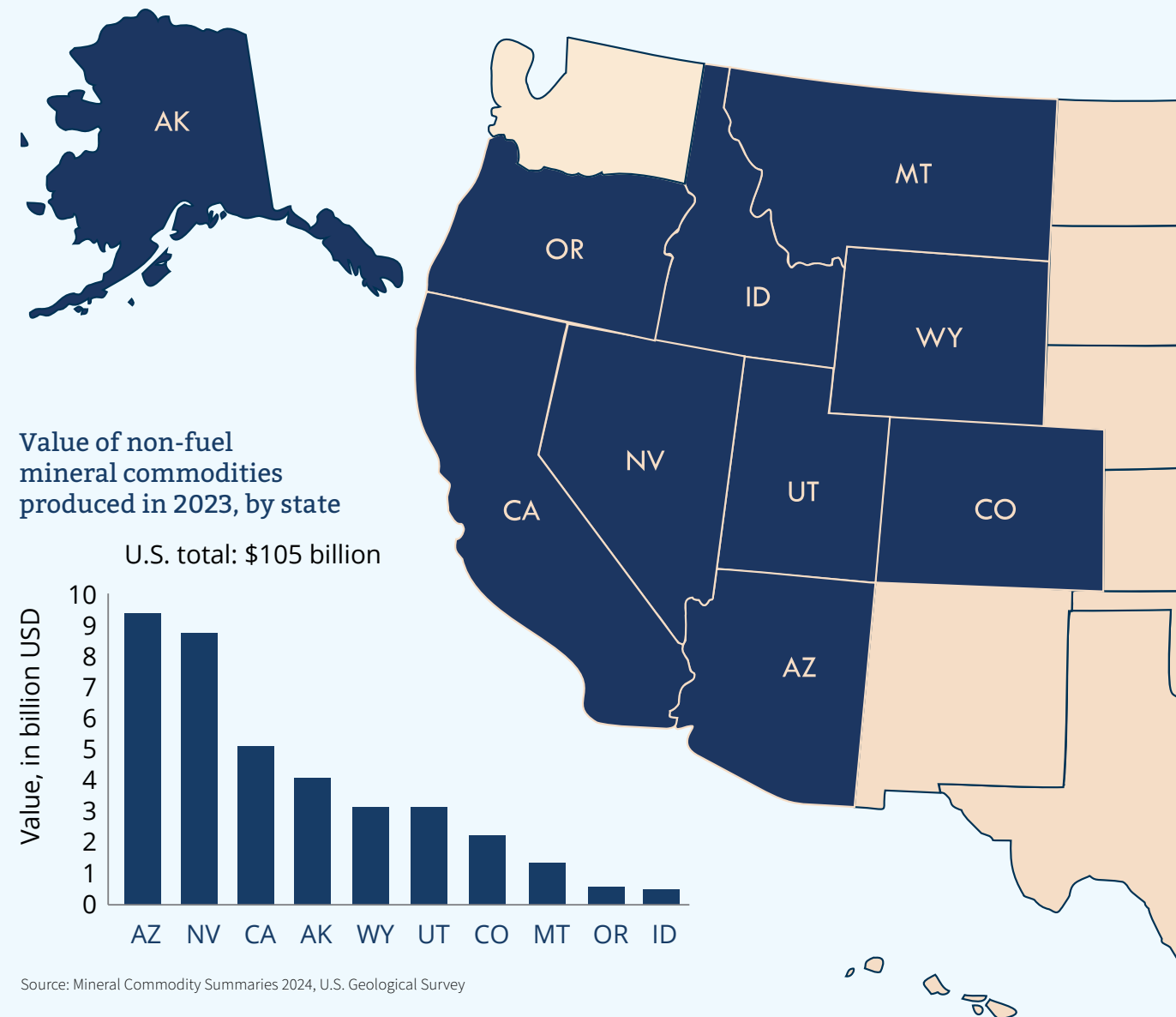
Tim Smith,
CEO and President,
US GoldMining

Wyoming

"Halleck Creek has a zero-strip ratio and consistent mineralization up to 300 m. We achieved 90% reclamation of processed material. Geologic characteristics favor leaching recoveries at 75-90 °C, making it less energy-intensive and cheaper."



Donald Swartz,
Former CEO,
American Rare Earths





Climate Change Resilience

Engineering and consulting for the future

Storm events are less predictable and more volatile. Droughts are intensified. Fires run rampant through the beetle killed pines across the Western USA. Mining is no stranger to harsh climates, however, climate hazards will only become more frequent and intense, imposing greater challenges to mining operations. Moreover, the US was one of the 195 countries that pledged to limit global warming below 2.0 degree Celsius under the 2015 Paris Agreement.

Miner Rio Tinto reported that record snowfall, twice the historical Utah average, contributed to a 36% reduction in mined copper production in Q1 2023 compared to Q1 2022. 7.5 million acres of the US, primarily in the West, burned in wildfires in 2022, leading to temporary shutdowns of mines. Mining operations face a critical dilemma: increasing production to help the world mitigate climate impacts, while a changing climate lowers production volumes. Engineering and consulting firms are working with miners to overcome this challenge.

Battling scarcity

The arid plains of the Western USA were once a boon for miners, as sparse vegetation and fewer trees facilitated exploration for mineral resources of the exposed rock. This dryness, however, is no longer a boon, and for some mining operations it could even be a bust. 30%-50% of production for copper, gold, iron ore and zinc is in areas of high water stress, and those figures are predicted to rise, according to a recent study by McKinsey & Company. Within the Western USA, the states of Arizona, Nevada and Utah are those most at risk. However, Colorado, Idaho and Wyoming are not exempt, as precipitation levels fluctuate drastically due to changing climate conditions.

Through utilization of innovative technologies, machine learning algorithms, storm prediction modelling, and other measures, engineering and consulting firms are trying to turn the future around for mining operations supplying domestic material for the USA's green energy transition. "Access to water is dwindling due to climate change's effects. The good news is that mining companies have long understood this issue and ensure they conserve these precious resources through immense pre planning for water use, closed-loop systems, dry stack tailings technologies, and other best management practices and conservation methods," said Steve Trussell, executive director at the Arizona Mining Association.

Jim Norine, vice president, minerals & metals Southwest USA at Ausenco, added: "At most sites, there are limitations on the amount

"We conducted a climate risk assessment for a mining complex in Nevada. Traditional climate models may not be reliable, so we must evaluate whether current structures can handle increased weather events over the mine's lifespan."

Paul Stockburger, VP and Sector Leader, Mining, Minerals & Metals, Stantec



of fresh water we can withdraw for operational use. Ausenco is deeply committed to minimizing freshwater demand and maximizing water reuse. We recently explored wastewater reuse on several projects; its adoption is increasing across the industry.

Another technology that has gained traction is coarse particle flotation (CPF), said Eric Wasmund, vice president global flotation business at Eriez. Floating at coarser sizes makes it easier to extract as much water as possible from tailings before they are deposited in tailings ponds. "CPF improves metal recovery by 3-6% and reduces water usage, as coarser material dewaterers more quickly," Wasmund said.

Adapting to extremes

As climate change accelerates, the mining industry faces unprecedented challenges in managing water resources. Intensified storms and unpredictable weather patterns demand a fundamental shift in the approach to water management.

Excess precipitation, as result of intensified storms for example, has the potential for catastrophic effects, like tailings overflow. For this reason, Knight Piésold includes climate change modelling as the foundation of their services. "We encourage clients to adopt a predictive site-wide water balance rather than a traditional water inventory tool. This approach allows for risk-informed decision-making regarding water needs, storage/freeboard requirements, and water inventory management. We aim to maintain operational water levels while avoiding excess inventory as the climate continues to change," explained Jeffrey Coffin, COO USA.

Image courtesy of Rio Tinto Kennecott

"We increasingly acknowledge the need to factor extreme climatic events into our designs and operational plans. Regulatory agencies are beginning to realize traditional storm return period designs may not be adequate for the long-term scenarios."

Jeff Parshley, Corporate Consultant, SRK



"For water management, machine learning can aid in the identification of various water types and is already frequently used to optimize performance of active or passive water treatment systems both in operations and closure."

Tom Meuzelaar, Founder and Owner, Life Cycle Geo



Accurate predictions depend on training models with the right data. Recent climate shifts are challenging traditional models. "Traditionally, we analyze climatic records over a seven-year period to identify the wettest years for our designs. Last winter's extreme conditions did not align with this data, resulting in unexpected challenges. We are now expanding our data analysis to include longer historical records, recognizing that periods of significant wetness occurred 100 years ago," recounted Jeff Parshley, corporate consultant of environment and mine closure at SRK.

Other firms observed that the rapid pace of climate change necessitates moving beyond reliance on recent historical record. "Over the past decade, there have been significant shifts in mining project design due to climate change. We can no longer rely solely on historical data for storm predictions. For instance, while working on drainage in Mexico, we faced a storm much more severe than expected," warned Norine.

Given the uncertainty of climate impacts, contingency planning is essential emphasized Rob Simm, SVP, emergent sector leader, water at Stantec: "Our models are not foolproof. In a project in Alaska, we are developing contingency plans in case our predictions are inaccurate."

Accepting that not everything can be predicted is key, echoed Paul Stockburger, VP sector leader, strategic pursuits, mining, minerals & metals at Stantec: "While we cannot predict every scenario, we apply probabilistic risk analysis to evaluate the likelihood of specific events. We aim to design for a high confidence level while focusing on realistic scenarios to protect operations effectively."

Climate change is a global issue impacting mining operations in every continent. Open communication and collaboration will be one way forward, and leaning from other jurisdictions is crucial emphasized Dennis Papiilon, executive president, global consulting at Ausenco: "We integrate lessons learned from different regions, not only focusing on climate change, but to understand big-picture impacts and create effective adaptation strategies."

The challenges posed by climate change to the mining industry are formidable, but not insurmountable. As extreme weather events become more frequent and water resources dwindle, the need for innovative solutions is more critical than ever. The future of mining in the Western US hinges on the industry's ability to innovate and adapt, ensuring resilience in the face of an uncertain climate. ■



A Date with Data

Technology firms help miners find love at first byte

Facing the challenge of increasing production without opening new mines in the Americas, Freeport-McMoRan turned to artificial intelligence, starting at their Bagdad mine in Arizona. Data access was not the problem—a data warehouse stores sensor data collected on a second-by-second basis from the company’s trucks, shovels, and stationary machines. The problem was creating and deploying an AI model at scale. McKinsey took the reins creating a model that boosted production by 5-10% and mitigated US\$1.5-2 billion of losses to build a new processing facility. “The project taught us to be more receptive to what the data was telling us,”

said Bertrand Odinet, chief information officer and chief innovation officer at Freeport-McMoRan in the McKinsey case study.

Data has long been a buzzword in the industry, much like AI, with vendors touting it as the key to optimize operations, reduce energy consumption, cut CO2 emissions, and boost productivity.

Without a doubt, data is the backbone of the industry’s advancements—it powers autonomy, AI, machine learning models, and nearly every modern shift in mining. “One of the biggest mistakes we see across the mining industry is doing things the way they have always been done, or worse, relying on “experience” to make decisions in the field without considering the data behind the decision. Sometimes our gut lies to us, and the data disproves our initial reaction to a problem we are trying to solve,” said Keaton Turner, founder, president and CEO of Turner Mining Group.

However, data alone is not enough. It is the collection, type, manipulation, and application of data that will provide the benefits that vendors promise. Data simply provides the ‘what.’ Technology providers in the Western US are working to use data to supply the ‘why’ and ‘how.’

Swipe Left

Data in the mining industry is like dating; just because there are billions of bits does not mean you will strike gold with every byte. Many vendors increased the number of sensors in hopes of collecting more data. Looks, however, are not everything: “Adding more sensors increases data volume, but not all data is useful, and if data is not enhancing decisions, the effort may not be worthwhile. To be effective, data must be captured, analyzed, and actionable for decision makers,” said Derek Cooper, vice president US and Canada at Hexagon.

Data amount is subject to goldilocks conditions. “Traditionally, data collection might occur monthly, biweekly, or even biannually due to the time-consuming nature of surveys, which meant mining operations relied on outdated geological models, missing critical changes that could affect production,” said Ravi Sahu, CEO at Strayos.

Strayos recently partnered with Wingstra, a drone manufacturing company, reducing the time needed to gather geotechnical data. “This increased frequency enables mining operations to maintain updated geological models, improving their mine planning and blast design,” continued Sahu.



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President and CEO,
Robbins



Ben McDonald,
Mining Solutions
Manager, Micromine



Lorraine Godwin,
Vice President
Commercial, VerAI



Eric Wasmund,
VP Global Flotation
Business, Eriez

That’s my type

The key is not the amount of data, but rather knowing exactly what type of data you need. High quality, unbiased data are best for training models (the AI kind). VerAI Discoveries, an AI-based mineral asset generator, leverages AI and machine learning algorithms to analyze geophysical data profiles— from magnetic, gravimetric, electromagnetic and seismic sources— of known economic ore bodies. By training their algorithms on this data, VerAI enhances the probability of identifying new economic mineral deposits.

Here is Lorraine Godwin, vice president commercial, on why unbiased data is so important: “Our improved success rate is primarily attributed to our rigorous approach to data utilization and AI model refinement. We prioritize high-quality, unbiased geophysical data. This approach minimizes interpretation errors and ensures our AI models are trained on the most accurate and reliable information available. By continuously advancing our AI algorithms through rigorous validation, we achieve higher success rates across different geological settings and mineral types.”

Made to perform

Once you find the right data match, it is all about performance. With the right data foundations in place, technology firms across the Western US are tailoring their models to specific deposits, thereby boosting productivity and saving valuable time. When given the proper data training, AI and machine learning (ML) are transforming the industry from the ground up.

Maptek is helping mining companies understand the true value of their resources by using AI to dig deeper. “We are witnessing significant AI adoption with Maptek DomainMCF, where ML analyzes drill hole or other sample data to create unbiased resource models. By considering structural elements and assessing data comprehensively, our cloud-based technology saves geologists from labor-intensive and time-consuming data manipulation. This innovation allows clients to generate preliminary models in hours instead of months,” said Clayton Fritz, sales manager of North America at Maptek.

Micromine is also playing the field with ML, streamlining the resource geologist’s workflow with Micromine Origin Grade Copilot, launched in November 2023. Ben McDonald, mining solutions manager, explained how the model leverages data to speed up resource estimation: “By leveraging advanced neural networks, Grade Copilot learns complex patterns in geological data to create comprehensive and robust models swiftly and autonomously. What once took weeks to accomplish manually can now be achieved in hours, and in some cases, mere minutes, freeing up valuable time for higher-level thinking.”

Yokogawa, meanwhile, is all about organizing the relationship— bringing structure to the data romance with their Collaborative Information Server. “By integrating the handling of all kinds of data from plant equipment, devices, and systems, this solution facilitates the optimized management of production activities across an entire enterprise,” said Greg Heiges, mining business development manager at Yokogawa.

And the relationship does not stop at the border. This server also contributes to the globalization of the mining industry. Peter Rowland, Canada solution sales manager, chimed in: “We share advancements and insights across regions; they are supported by tools such as the Collaborative Information Server, which provides remote data access.”

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Performance anxiety

In the complex and ever-evolving world of data-driven solutions, it is easy to feel overwhelmed, especially when every provider seems to have a different idea of what is best. The lack of standardization among technology providers only adds to the already significant and sometimes daunting complexity. As Matt Blattman, director of technical services at Hecla Mining, pointed out in Seequent's "Beyond the Hype: How technology can drive mining operations' performance" Insights Paper: "We would like to standardize, but within our own company, with four different mines, four different types of deposits, and four different mining methods, it is hard to find something that fits every situation."

This challenge has led leading data solution providers to fine-tune their approaches, ensuring they are not just offering a one-size-fits-all solution, but something more deeply tailored and highly personalized. As Sahu puts it: "During onboarding, we understand the specific problems and KPIs the client wants to address. Within the first six months, we achieve at least one KPI improvement. The AI model becomes more calibrated to the specific site as we gather more data—around 5,200 data sets are required to achieve accuracy."

This gradual, get-to-know-you approach allows operators to dip their toes in before taking the plunge. This is crucial as it builds confidence and fosters trust in the new technology. And it is paying off: "When clients see the value, they are more inclined to extend their contracts and integrate our platform further into their operations," Sahu added.

Life Cycle Geo, a firm specializing in ML services, observed a similar trend, said Tom Meuzelaar, the founder and owner: "Model performance improves as operators collect more data. However, gaining buy-in and trust from operators when it comes to ML is typically a gradual process. Operators need to see tangible benefits—such as time and cost savings—and understand how a machine learning approach improves upon established practices before fully committing to new models."

Ultimately, finding the right solution is like finding the right partner—it is a journey that requires exploring different options and assessing how well they align with your needs. Sometimes, you need to go on a few 'data dates' before you find the perfect match. The process may seem slow, but it is essential for long-term success.

Remember, before you say, "I do", that it is all about compatibility and performance. High-quality, relevant data forms the foundation for a successful partnership, allowing both parties to bring out the best in each other. There is no need to rush the relationship because once the perfect match is made, the relationship will blossom, allowing for significant productivity gains and smarter decision-making. It is not just about the initial attraction; it is about long-term compatibility and growth. True success comes from continually refining and enhancing models, ensuring they remain aligned with the ever-evolving needs of the operation. It is also beneficial to note that not all relationships are meant to last. Flexibility and a willingness to evolve are vital. In the end, the key to a lasting relationship is finding a partner that not only meets your needs today but is adaptable enough to grow with you into the future. ■

Executive Insights

On Talent

"The mining industry is currently contending with significant macro trends that hinder effective data utilization, most notably the shortage of skilled talent such as mining engineers and geologists."

Rob Hardman, President and General Manager, North America, Maptek



"We will likely receive over 20,000 employment applications, an increase from 2023's 11,000. This surge reflects our robust social media efforts to promote our brand and highlight opportunities within the mining sector."

Keaton Turner, Founder, President and CEO, Turner Mining Group



"To tackle workforce challenges, we established a training center with simulators for underground haul truck operators and muckers. Trainees experience real-world scenarios in a safe environment."

Keith Jones, General Manager, Small Mine Development



"The labor shortage has impacted everyone in the industry. To counter this, we leverage technology to produce results for our clients faster than in the past, using technologies like LiDAR."

Dagny Odell, Owner, Practical Mining



On Data

"AI-based strategies are becoming more recognized, especially for complex decision-making, asset condition analysis, anomaly detection, and predictive maintenance. Rapid advances in computing power make these developments feasible."

Steffen Gjorvad, President, TAKRAF USA



"More frequent data collection means operators can address issues before they escalate, leading to proactive risk management. Safety is paramount in the mining industry, and our technology helps provide data that highlights risk factors."

Ravi Sahu, CEO, Strayos



"AI has exploded in the last 12 months, transforming from a side discussion to a necessity. We Integrated GIS with AI to create exploration targets. We see this as the future."

Chris Summers, CFO, Burgex Mining Consultants



"Our hardware captures data for production analysis, revealing how effectively equipment is used. Customers can identify ways to boost production without new investments."

Ashok Amin, Segment Manager, Americas, Bulk Material Handling, Bosch Rexroth



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Decarbonization: Extraction and Processing

Innovation and collaboration are the only way forward

The United Nations' Intergovernmental Panel on Climate Change (IPCC) indicated that to limit the global temperature rise to 1.5°C will require rapid, far-reaching, and unprecedented changes; human-caused CO2 emissions must decrease 45% by 2030 and reach net-zero by 2050. Mining accounts for 4-7% of global greenhouse-gas emissions, according to McKinsey. The path to net-zero carbon emissions is a global, multi-sector challenge, and developing road maps to achieving that goal requires industry commitment, innovation and new technological solutions.

The challenges to achieving decarbonization road maps in the mining industry need to be tailored by operation, addressing the key

pillars of decarbonization: energy efficiency, hybrid power, microgrid integration, alternative vehicles, mine design, and process adaptation to alternative energy sources. In the Western US, contractors and tunnel construction, material handling and comminution firms are working diligently to find ways to reduce emissions.

For traditional drill and blast methods, each ton of explosives is approximately equivalent to a thousand liters of emitted CO2. Typical consumption rates for explosives in underground mines can range from 0.5 to 1.0 kg/t of rock mined. If a mine processes 10 million t/y of rock, for example, the explosives required could range from 5,000 to 10,000 kg. This amount multiplied by emitted CO2 per ton becomes significant. After extraction of ore, crushing and grinding can consume up to 53% of the total energy used in a mining operation and account for approximately 46% of the total GHG emissions from the entire mining and processing operation, according to a study published in Nature. Luckily for firms in the Western US, there is an alternative for both processes: mechanical cutting.

Robbins invented tunnel boring machines (TBMs) for civil industry but is adapting this technology to mining. "We are conducting studies worldwide to mine ore with TBMs. These machines offer several advantages: enhanced safety, reduced underground workforce, and TBMs act as primary crushers. The rock comes away from the tunnel face already crushed, ready to be conveyed up shafts or vertical conveyor belts," said Lok Home, the firm's president.

Focusing on flotation can also provide energy saving benefits in the mill circuit. Coarse particle flotation (CPF) is a relatively new technology used to recover particles larger than 150 micrometers. Eriez, pioneered the technology through development of HydroFloat, which has been implemented globally. "HydroFloat allows for flotation at a coarser size, reducing the need for fine grinding. This can cut grinding energy consumption by about two and a half times, lowering overall concentrator energy use by 10 to 20%," said Eric Wasmund, vice president of their global flotation business.

Eriez also offers magnetic mill liners, which, according to, Jose Marin director of minerals and materials processing, "can last three to five times longer than rubber or metallic liners, reducing the frequency of replacements." This longer lifespan reduces the carbon emissions needed to manufacture new mill liners.

The mining fleet is one of the primary sources of on-site GHG emissions. For surface mines, mobile mining equipment can account for up to 30% of GHG emissions. This rises to 80% for mines lacking onsite smelting or refinery facilities. Large mining haul trucks alone

"ESG is an overriding concern for the industry. Companies are demanding conflict-free production and assistance with energy management and decarbonization goals. Tier 1 companies focus on minimizing their impact from pit to port."



Greg Heiges, Mining Business Development Manager, Yokogawa

represent more than 50% of a surface fleet's emissions.

One way to lower this footprint is through autonomous technology, said Darrell White, group executive Americas at Thies: "Autonomous technology is a significant focus as it increases efficiency, leading to lower consumption of diesel and ultimately fewer emissions."

The solution is gaining traction, said Peter Rowland, account manager Canada at Yokogawa: "The shift from industrial automation to autonomy is accelerating. For instance, trends in Chile will influence North America and the rest of the world. We share advancements and insights across regions."

Arizona-based Freeport-McMoRan took important strides during 2023 toward decarbonization efforts. The miner approved a new project to convert the fleet of 33 haul trucks at their Bagdad operation in Arizona to become fully autonomous by 2028. While full electrification yet, converting to full autonomy is an important step and it will make an impact when it comes to greenhouse gas emissions. Emissions from haul trucks are projected to decline because of reductions in idle time and increased efficiency. Idle time is projected to decrease by 10,000 hours, according to the firm's Climate Report.

Trucks, or course, are not the only material handling method, and, given shifts in the Western US mining sphere they are not the

most efficient solution either. Steffen Gjørsvad, president of Takraf USA, elaborated: "Emissions from trucks are significantly reduced using conveying systems, and the logistics of moving trucks in tunnels is complicated. We see more applications using conveyors due to their efficiency, requirement for higher volumes due to decreasing ore grades and the trend to move from open-pit mines to underground operations."

Traditional conveying systems, however, can account for 80% of a mine's energy consumption, rising Scope 3 emissions. Takraf utilized innovation through partnership with ABB to introduce gearless drive technology, which reduces energy consumption 6-10% and reduces direct emissions: "A study showed that CO2 emissions compared to diesel truck engines for the same copper production volume were reduced by 66% when using gearless drive technology," highlighted Gjørsvad.

At Freeport-McMoRan's Chino mine, Bosch Rexroth replaced aging gearboxes and electric motors with advanced drive systems. Ashok Amin, segment manager Americas of bulk material handling, explained the benefits: "Replacing a single 1,500 horsepower drive with a modular system of three 300 horsepower motors enables us to shut off motors during lower demand periods, resulting in substantial energy savings. This modular approach enhances operational efficiency and newer technologies are specifically designed to reduce energy consumption."

Every mining operation is different so the path to reducing emissions starts with monitoring how much an operation emits. This monitoring, however, can have unforeseen benefits, said Keith Jones, general manager at Small Mine Development: "We regularly conduct emissions-based exhaust testing, which involves measuring emissions parameters like carbon monoxide and nitrogen oxides using a tailpipe analyzer. We found that this testing helps diagnose engine issues."

The solutions for emission free operations exist and are advancing rapidly. It is only a matter of adoption and foresight. "Environmental stewardship must be part of the overall strategy from the start. Anticipatory practices help our clients achieve their environmental goals while maintaining operational efficiency," said Dagny Odell, owner of Practical Mining.

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Net zero is a paradigm shift that requires collaboration among all industry players: “The transition to sustainable energy and addressing climate change are global issues far beyond any single company’s balance sheet. To tackle these challenges effectively, we will need a higher level of partnership between mining companies and external agencies over the next 20 to 30 years than we have seen in the past century,” emphasized Nathan Foster, managing director Kennecott at Rio Tinto.

Even within this short article, collaborative efforts brought dramatic change. Takraf partnered with ABB. Eriez created a consortium with the University of Queensland including industry leaders like Rio Tinto, Newmont, Newcrest, Anglo American, and Oz Minerals to develop CPF technology. The industry is making headway, only time will tell if it will be enough.

Decarbonization in the mining industry will be a global effort, as we all share one planet. Recent years have seen a reaffirming of decarbonization efforts worldwide, for the benefit of the industry and broader humanity. Anglo American partnered with EDF Renewables in 2022 to develop a regional renewable energy ecosystem. This supplies operations with clean power and provides energy to South Africa, a country stricken by power outages. FPX Nickel is exploring carbon sequestration through mine tailings. By utilizing the natural carbon capture potential of ultramafic rock in mine tailings, FPX aims to offset a significant portion of its emissions. The company works with researchers to enhance this process, potentially allowing certain mines to achieve net-negative CO2 emissions. ■



GLOBAL BUSINESS REPORTS

Western USA Mining 2024-25

Pre-Release Edition

This publication is a pre-release edition of GBR’s reports on Western USA Mining, that will be published in Q4 2024 and Q1 2025.

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Cover image courtesy of Rio Tinto Kennecott

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