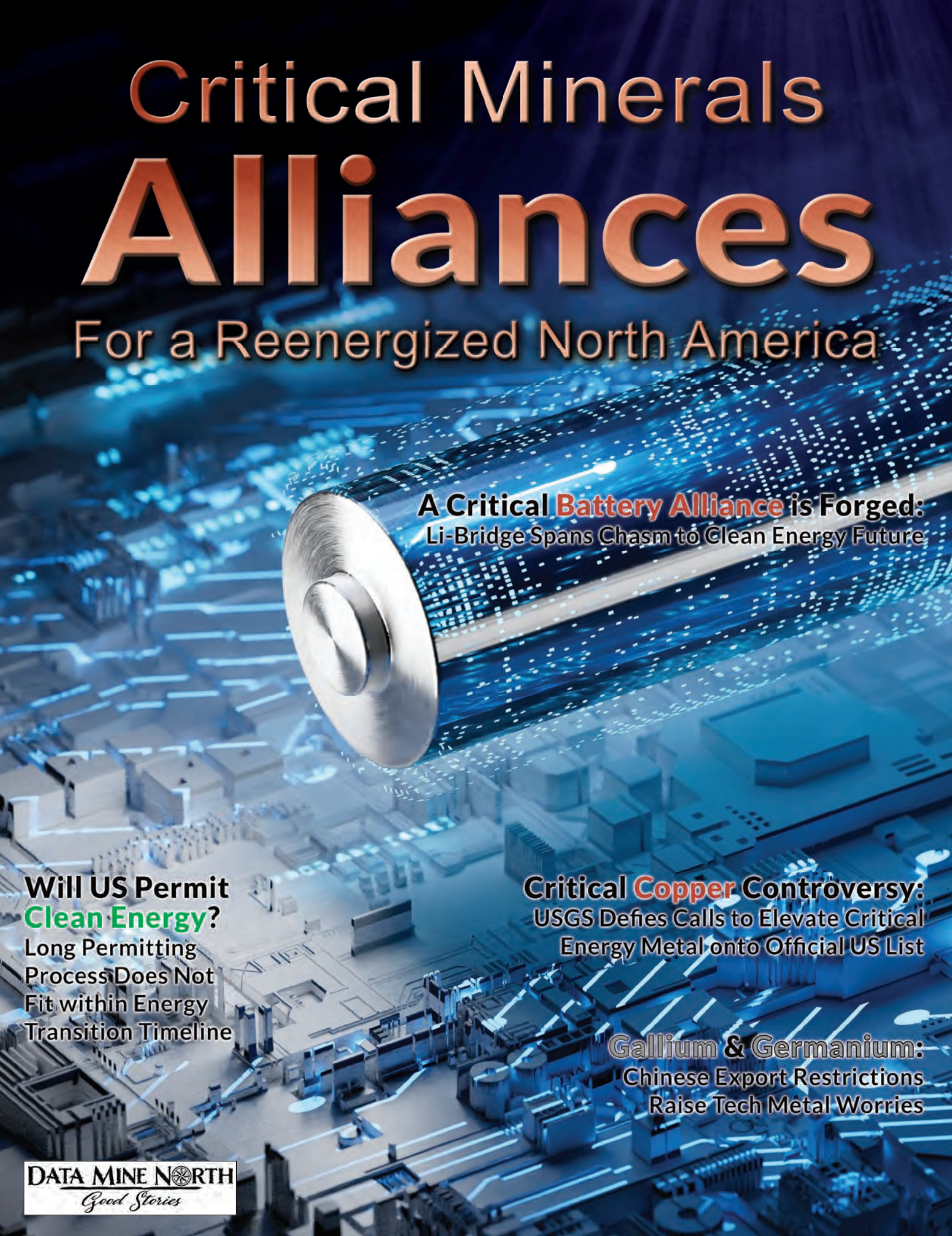
# Critical Minerals Alliances

## For a Reenergized North America



**A Critical Battery Alliance is Forged:**
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USGS Defies Calls to Elevate Critical Energy Metal onto Official US List

**Gallium & Germanium:**
Chinese Export Restrictions Raise Tech Metal Worries

DATA MINE NORTH
*Good Stories*

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## INTRODUCTION



## CRITICAL MINERALS POLICY



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**Critical Minerals Alliances**
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# Contents




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The world has all the pieces to achieve an envisioned clean energy and high-tech future, but they are fragmented. Alliances being forged in North America and around the globe are beginning to assemble those fragments into a well-oiled machine.
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# Critical Mineral Alliances are Forged

## For a healthy, prosperous, and exciting future for humankind

**DATA MINE NORTH LAUNCHED** the first edition of Critical Minerals Alliances in 2021 with the hopes that this annual magazine would play some small role in helping to build alliances "that are not crippled by irreconcilable differences between organizations and individuals that do not always see eye-to-eye but strengthened by a spectrum of ideologies with a common goal – a healthy, prosperous, and exciting future for humankind."

SHANE LASLEY

Today, the alliances envisioned by the Data Mine North team are beginning to coalesce, and these partnerships are developing cohesive strategies for sustainably mining, refining, and recycling the elements of 21st-century innovation.

These critical minerals alliances range from international partnerships between nations like Australia, Canada, and the United States, to community and state groups like those being forged at the Salton Sea – an area of Southern California known as Lithium Valley.

>> *Geopolitical ramifications aside, diversifying and shortening critical minerals supply chains is better for the planet, especially when those minerals are produced in countries with strict ESG standards."*

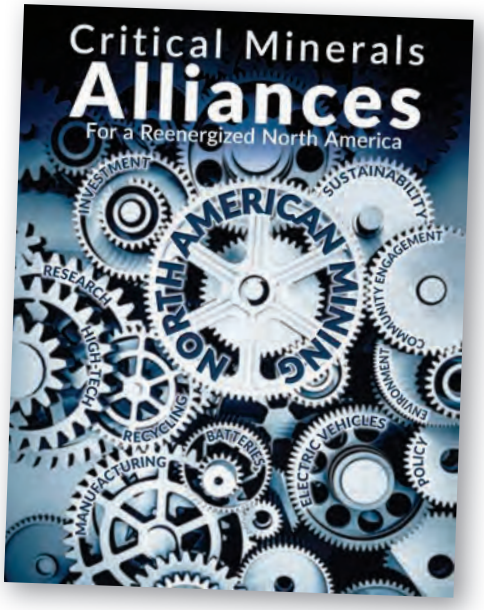
*–Shane Lasley*

The community and state partnerships that have come together in support of establishing a lithium battery supply chain in California's Lithium Valley is a prime example of the critical alliances that can be formed around American minerals projects that put the environment at the fore.

Controlled Thermal Resources' plan to utilize zero-carbon geothermal energy below its Hell's Kitchen project on the shores of the Salton Sea to power the extraction of lithium from the hot

brines that generate that steam and then convert this raw product into green battery-grade lithium needed for America's EV revolution is something even So-Cal residents and the state's governor can get behind.

"The future happens here first – and Lithium Valley is fast-tracking the world's clean energy future," California Gov. Gavin Newsom said during a visit to the So-Cal lithium project.




### Bridging the chasm

The one North American battery materials alliance to rule them all is Li-Bridge – a group assembled to span the wide chasm that lies between the present and ambitious visions of a green energy future where electric vehicles are charged with low-carbon energy.

Convened by the U.S. Department of Energy, Li-Bridge is a public-private partnership committed to accelerating the development of a robust and secure domestic supply chain for lithium-based batteries.

"While the U.S. has all the pieces to achieve these goals, they are fragmented. The Li-Bridge alliance will bring these pieces into a cohesive whole," said Venkat Srinivasan, director of the Collaborative Center for Energy Storage Science at Argonne National Laboratory. Li-Bridge and other critical minerals alliances uniting around the globe are beginning to bridge the wide gulf between the fossil fueled 20th century and the envisioned clean energy future.

### International alliances

Even with the hard work being done by the local and national energy transition alliances already formed, there is much more bridge building yet to be done.

International Energy Agency Executive Director Fatih Birol said the IEA team is "encouraged by the rapid growth in the market for critical minerals, which are crucial for the world to achieve its energy and climate goals," but "major challenges remain."

"We see an urgent need to bring together governments, industry, investors and other stakeholders to collectively address questions that will have a profound impact on the future of energy security and global efforts to reach net-zero emissions," he added.

Australia, Canada, and the U.S. are addressing this at the international level through an alliance to better define the critical minerals these countries have to offer.

Under the tri-national Critical Minerals Mapping Initiative, these countries merged geological, geophysical, and mineral resource information into a single dataset that is expected to enhance critical mineral discovery.

"Geology doesn't stop at the border and neither does our data," said U.S Geological Survey scientist Anne McCafferty. "Scientists will now be able to look at geological and geophysical data seamlessly across both Canada and the United States, as well as make direct comparisons to Australia."

America's heavy dependence on countries like China for critical minerals and an overall lack of knowledge about many of these elements essential to clean energy, high-tech devices, and military hardware was a primary driver behind the formation of CMMI.

### Geopolitical chess pieces

The geopolitical ramifications of America's reliance on imports for critical minerals came to the fore with China's gallium and germanium export restrictions.

While the markets for this pair of tech metals are minuscule in comparison to the economies of the U.S. and China, they have tremendous economic leverage due to their uses in high-tech and green energy products.

Gallium serves as a primary ingredient in semiconductors used in next-generation smartphones, telecommunication networks, LEDs, thin-film solar cells, and medical devices.

Germanium is a powerful ingredient in fiber optics, night vision devices, triple-layered solar panels, and transistors for classic and quantum computers.

China produces 98% of the world's gallium and is the source of 54% of the germanium that America imports.

Analysts and foreign policy experts see China's export limitations on this pair of metals as a counter to the U.S. and other western nations imposing restrictions on the exports of computer chips and related technologies to China.

"Gallium and germanium are chess pieces in a geopolitical game of enormous proportions," Christopher Ecclestone, a mining strategist at the consulting firm Hallgarten & Company, told Washington, DC-based Foreign Policy.

### Rallying critical minerals alliances

While China's dominance in the production of gallium and germanium makes these tech metals critical pieces in the geopolitical chess match between China and the West, putting these pawns into play may have the unintended consequence.

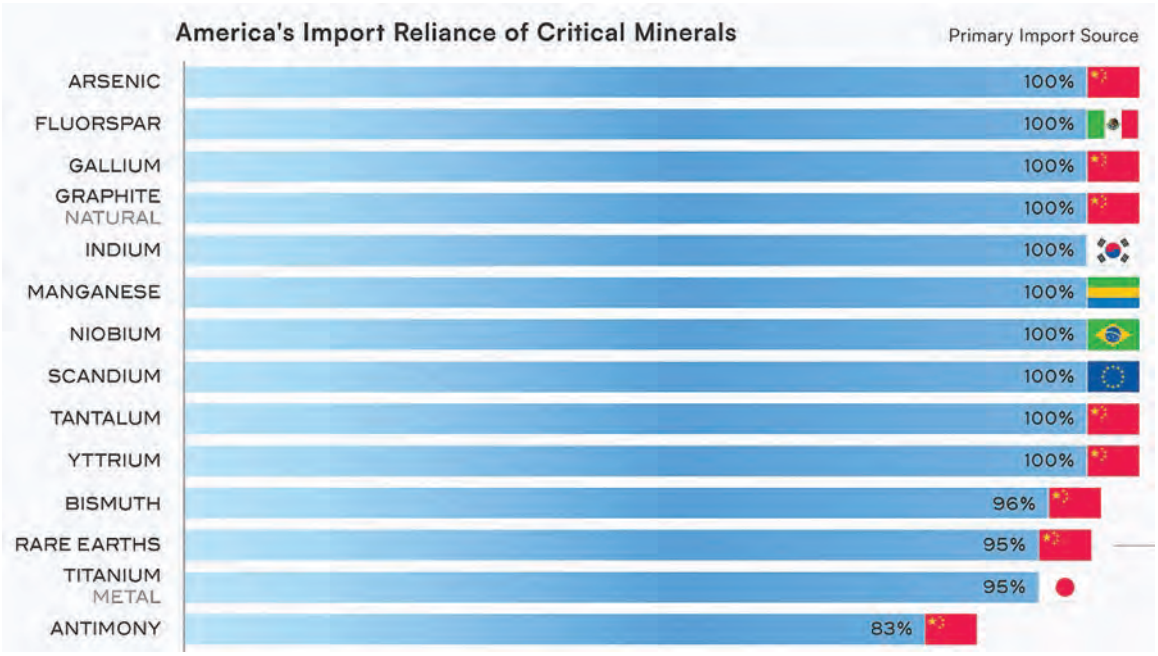
"The export controls on gallium and germanium are already putting pressure on countries to consider alternatives and will continue to erode China's market dominance for critical materials," penned Sarah Godek, a Stimson Center research analyst that specializes on China.

If China's export restrictions have the desired effect – limit the West's ability and drive up the cost to produce the chips that go in electronics ranging from toys and home appliances to vehicles and military hardware – they will also likely rally citizens and businesses to get behind critical mineral alliances aimed at further eroding China's tech materials dominance.

Geopolitical ramifications aside, diversifying and shortening critical minerals supply chains is better for the planet, especially when those minerals are produced in countries with strict ESG standards.

This is why the Data Mine North team is proud to present Critical Minerals Alliances 2023 – the third edition of an annual magazine that encourages the formation of critical mineral "partnerships that are not crippled by irreconcilable differences but strengthened by a spectrum of ideologies with a common goal– a healthy, prosperous, and exciting future for humankind." DMN

VISUAL CAPITALIST




# US minerals reliance raises red flags

## Visual Capitalist Infographic shines light on America's heavy reliance on China, others for critical minerals

By SHANE LASLEY
DATA MINE NORTH

**A RECENT INFOGRAPHIC** produced by Visual Capitalist raises both figurative and literal red flags when it comes to America's reliance on imports for the minerals and metals critical to the nation's high-tech sectors, military readiness, and envisioned low-carbon energy future.

While the United States' heavy dependence on other countries for critical minerals is not new to those who follow the metals and mining sectors, Visual Capitalist's unique ability to present complex data in a visually compelling and easy-to-understand format underscores just how heavily America leans on others when it comes to specialty minerals.

If you count the 14 rare earth elements individually (which is how they are presented on the U.S. Geological Survey list of 50 critical minerals), America depends on other countries for more than 95% of its needs for 26 minerals – 20 of which are primarily sourced from China.

In addition to the rare earths that go into a broad range of high-tech and consumer goods, this list of minerals America depends predominantly on China for the bulk of its supply includes gallium, a semiconductor metal used in computer chips; graphite needed for the lithium-ion batteries powering electric vehicles and broad range of portable electronic devices not tethered to an outlet;

*>> While the United States' heavy dependence on other countries for critical minerals is not new to those who follow the metals and mining sectors, Visual Capitalist's unique ability to present complex data in a visually compelling and easy-to-understand format underscores just how heavily America leans on others when it comes to specialty minerals.*

and tantalum used extensively in miniaturized electrical circuitry in smartphones and other devices.

"Even as our mineral needs skyrocket for everything from electric vehicles to advanced energy technologies and critically important defense systems, the U.S. is stumbling when it comes to our supply chains," National Mining Association COO Katie Sweeny said in January, when the USGS data underlying the Visual Capitalist infographic was published. "We have never been more dependent on China and others for the minerals that are absolutely essential to modern life and, with each new announcement of a blocked mine or a foreign sourcing agreement with countries that have questionable labor practices, we are locking in our position of competitive weakness."

## Geopolitical implications

America's critical import dependence, and the geopolitical implications that come with that, are underscored by China's implementation of state-controlled restrictions on the exports of gallium and germanium.

Gallium serves as a primary ingredient in semiconductors vital to next-generation smartphones, telecommunication networks, automobile electronics, LED lights, thin-film solar panels, and medical devices.

Germanium is a powerful ingredient in fiber optics, night vision equipment, triple-layered solar panels, and transistors for classic and quantum computers.

Various semiconductor products made from both critical tech metals are used to make the computer chips in virtually every electronic device.

According to the USGS, China produced 98% of the world's gallium during 2022 – Russia came in second at around 1%. When it comes to germanium, 54% of America's imports come from China.

As of Aug. 1, Chinese companies must get special government permission to ship this pair of tech metals to buyers outside of the country.

These curbs are seen as a geopolitical response to the CHIPS Act and other actions taken by Washington lawmakers to limit the export of microprocessor technology to China.

"Gallium and germanium are chess pieces in a geopolitical game of enormous proportions," Christopher Ecclestone, a mining strategist at the consulting firm Hallgarten & Company, told Foreign Policy.

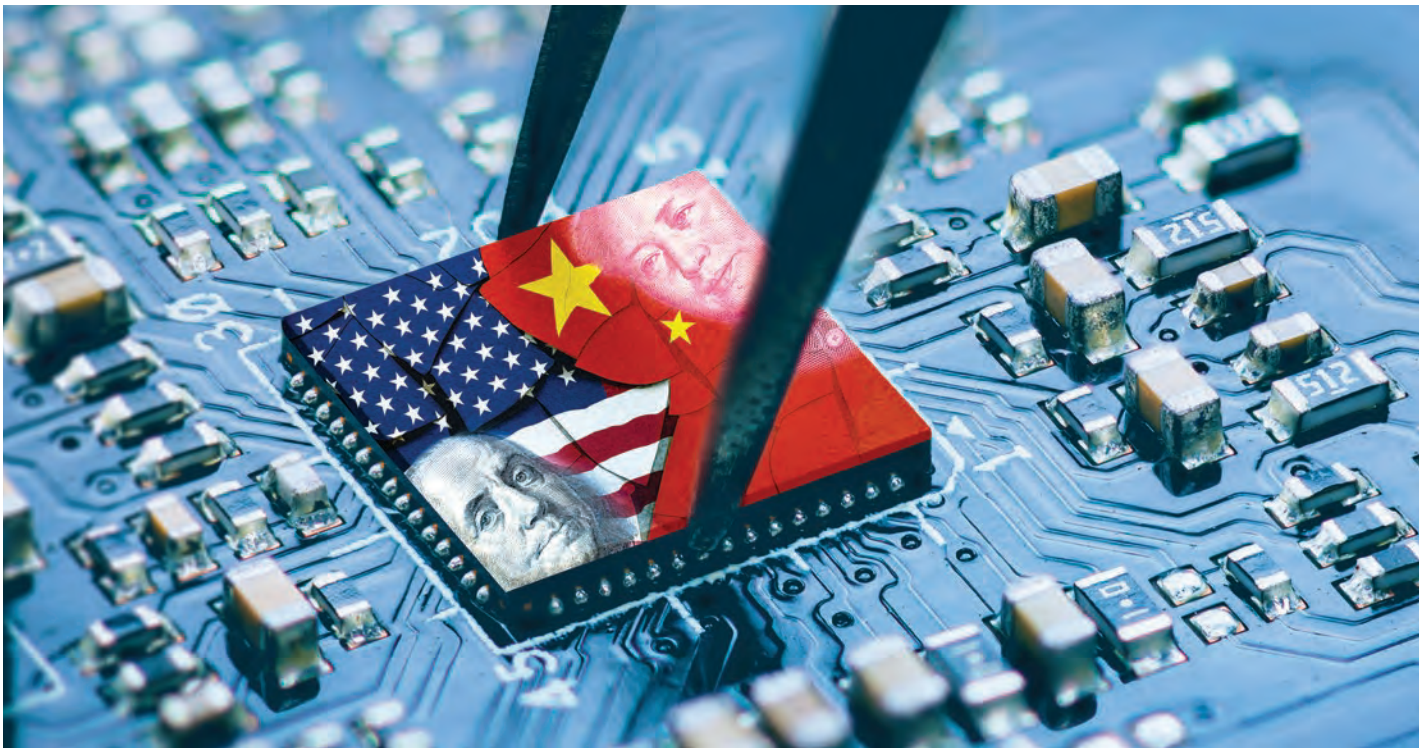
Considering that the U.S. is import-dependent for 41 different minerals and metals, and China is the primary provider for 23 of them, America is at a raw materials disadvantage in this geopolitical chess match.

This weakness has raised red flags for senators James Lankford, R-Okla., Mitt Romney, R-Utah, and Gary Peters, D-Mich., who introduced a bill in June to create an intergovernmental task force to identify opportunities to increase domestic production and recycling of critical minerals.

"Relying on China for critical minerals means relying on our adversary for batteries, medical supplies, and military equipment," said Lankford. "We need to prioritize American-produced and made energy solutions and give U.S. suppliers a seat at the table."

The senators hope this task force will shrink the red-flag-raising list of U.S.-imported critical minerals presented on the Visual Capitalist infographic.

"Our nation's dependence on adversarial nations like China for critical minerals poses serious national security and economic threats," said Peters. "This bill will strengthen our domestic critical minerals supply chain, create good-paying jobs, and ensure our advanced manufacturing sector can continue to compete on the global stage." DMN



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China's gallium and germanium export bans are believed to be a countermove to the CHIPS Act and other plays made by the United States, Japan, and Netherlands to restrict the export of semiconductors,, as well as chipmaking technologies and equipment to the Middle Kingdom.

GENERAL MOTORS

America's rapidly expanding electric vehicle sector depends on a robust and reliable supply of battery materials.

# Bridging the US battery supply chain chasm

## Li-Bridge alliance assembles to span $1 trillion energy rift

By SHANE LASLEY
DATA MINE NORTH

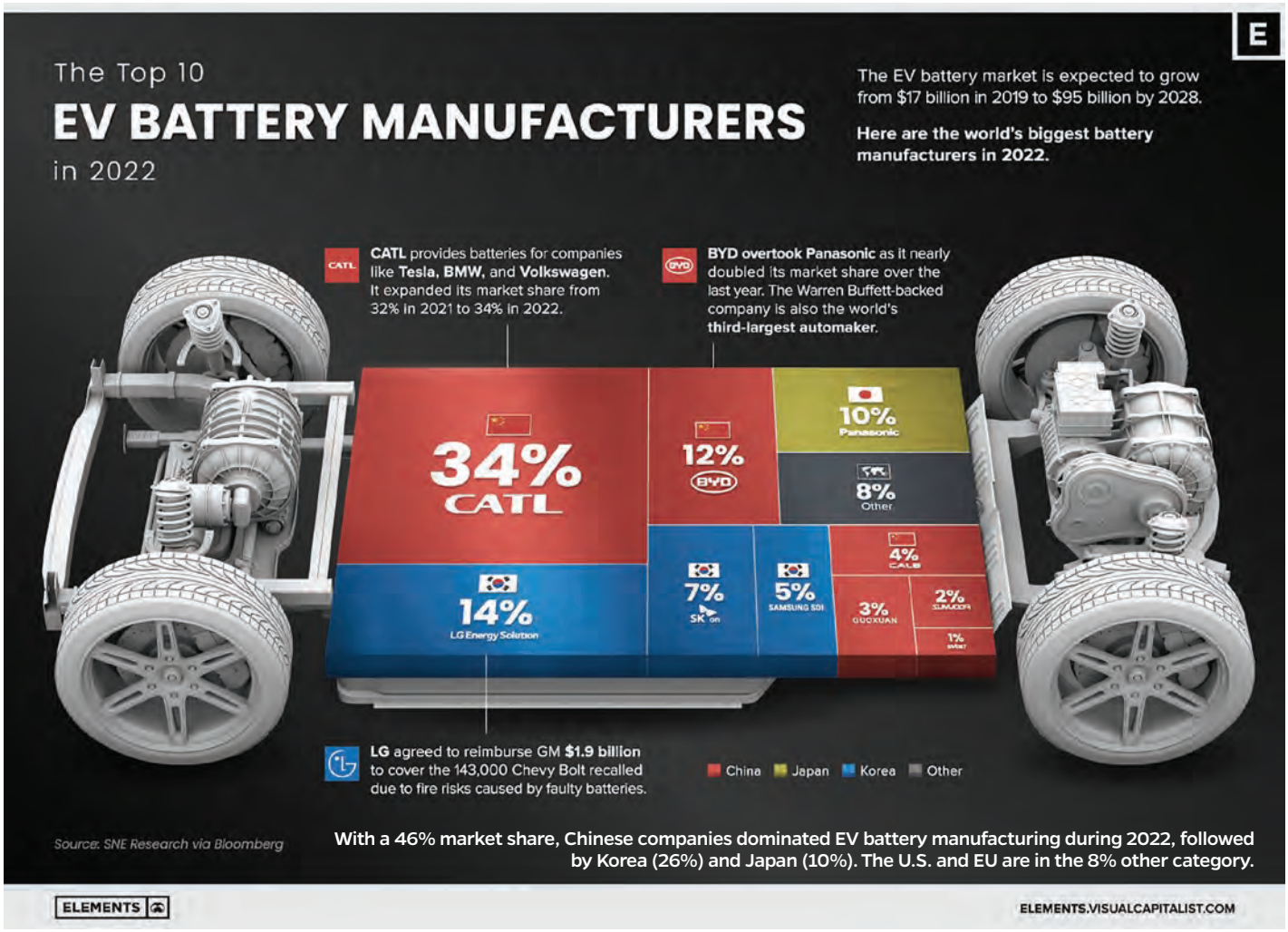
**THERE IS NEARLY A $1 TRILLION CHASM** between where the United States' lithium battery supply chain is today and where it needs to be by 2035 in order to build the envisioned green energy future where electric vehicles are charged with low-carbon energy. Roughly 40% of this investment will need to go toward ensuring there is a plentiful supply of cobalt, graphite, lithium, nickel, and other battery materials.

Simon Moores, CEO of Benchmark Mineral Intelligence and one of the world's foremost authorities on lithium battery supply chains, has dubbed this wide abyss the "great raw materials disconnect."

"A disconnect where the mine supply is going about half the pace of battery EV demand. And that gap is going to take a long time to bridge, it's going to take more than this decade to bridge," he said during the opening address of Benchmark's Battery Gigafactories USA 2023 conference in Washington, DC.

Amongst the crowd listening to Moores' impassioned battery supply chain speech were members of Li-Bridge, an alliance of America's national laboratories and companies along the entire lithium battery supply chain that was assembled for the very purpose of bridging the rift that lies between today's lithium supply chain realities and the clean energy future.

"Li-Bridge is optimistic that the U.S. industry can build sustainable competitive advantages, overcoming any comparative disadvantages the United States may have in the form of higher costs or a lack of critical mineral resources and enabling the U.S. industry to thrive without perpetual government support," the public-private alliance penned in its Building a robust and resilient U.S. lithium battery supply chain report published in February.




## Forging a battery alliance

Created as a vehicle to accomplish the directives laid out in President Joe Biden's Executive Order on America's Supply Chains, Li-Bridge was convened by the U.S. Department of Energy in 2021 and is helmed by Argonne National Laboratory, which is known for its ability to move battery innovations from the lab to the market.

Understanding that bridging the great lithium battery supply chain disconnect will require an all-hands-on-deck effort, Argonne forged alliances with three U.S.-based groups – NAATBatt International, NY-BEST, and New Energy Nexus – that represent more than 600 industry stakeholders across the battery ecosystem.

"While the U.S. has all the pieces to achieve these goals, they are fragmented. The Li-Bridge alliance will bring these pieces into a cohesive whole," said Venkat Srinivasan, director of the Argonne Collaborative Center for Energy Storage Science.

After more than a year of meetings with its members, Li-Bridge published a national blueprint with 26 key steps to ensuring the U.S. has a reliable supply of the critical minerals, manufacturing capacity, and talent to establish a robust and sustainable supply chain for lithium battery technology that will power the clean energy transition in North America.

"From enabling renewable energy and providing reliability and resilience for our electric grid to powering our future electrified transportation systems, batteries are at the center of the clean energy transition," said NY-BEST Executive Director William Acker.

## Starting from behind … China

Li-Bridge and its government and private sector members, however, know that the U.S. has already fallen well behind Asia and Europe when it comes to building lithium battery supply chains, and even if the strategy outlined in its blueprint is followed precisely, the nation will not achieve complete lithium battery supply chain independence by 2030.

"Although we are starting to see activity in the domestic battery manufacturing sector thanks in large part to the Bipartisan Infrastructure Law and the IRA (Inflation Reduction Act), U.S. industry is still 10 to 20 years behind Asia, and about five years behind Europe, in commercializing manufacturing of this critical technology," said NAATBatt International Executive Director James Greenberger.

China, which recognized the importance of lithium battery technology nearly two decades ago, has positioned itself as a dominant global player along the entire supply chain.

Moores addressed China's jump on the rest of the world when it comes to critical mineral and lithium battery supply chains during his keynote address in Washington.

"China's forward thinking and aggressive industrial strategy to build gigafactories, chemical and critical mineral refining plants has ensured the flow of the world's key raw materials is towards China. As a result, huge downstream value is created," the Benchmark CEO and founder said. "Today, Benchmark data shows 80% of the world's lithium-ion batteries are made in China."

He advised the attendees of the lithium battery supply chain conference in the nation's capital that a U.S. strategic decoupling from China will require the development of a robust domestic supply chains that sit alongside this global supply chain base.

"This makes building mines, chemical plants and gigafactories here – at speed and at scale – of paramount importance, regionally and globally," the Benchmark founder and CEO said.

Li-Bridge agrees with Moores assessment and adds that establishing a domestic lithium battery supply chain under U.S. laws and standards offers enormous ESG advantages over sourcing these materials from countries with far less concern for the environment and human rights.

"Reshoring supply chains reduces environmental footprints and builds social resilience during the energy shocks we're facing this decade," said New Energy Nexus CEO Danny Kennedy.

### Three challenges to overcome

With a later start and weaker foothold, Li-Bridge says the U.S. needs to take definitive actions if it is going to overcome domestic challenges that threaten to thwart the building of a robust and sustainable domestic lithium battery supply chain that extends from the mines supplying battery materials to the American EV drivers charging those batteries with renewable energy.

This transition to low-carbon energy is expected to drive a massive 600% increase in lithium battery demand in the U.S. by 2030.

Benchmark calculates that at least $514 billion will need to be invested across the global battery supply chain by 2030 and $920 million by 2035. More than 40% of these investments need to be made in mining, and to a lesser degree recycling, to ensure there is a plentiful supply of raw materials.

"Battery makers, OEMs, and indeed countries – especially the world's leading economy here in the US – need joined-up thinking for this," said Moores.

Aside from the geopolitical risks inherent with being heavily reliant on imports from China, this rapid rise in demand for batteries and the materials they are made from has American automakers and battery manufacturers competing in a global market where demand is outpacing supply.

And, with U.S. military equipment increasingly dependent on lithium-based batteries, relying on imports for the raw materials and components for these batteries is a strategic risk to the nation.

Moores said this has thrust lithium-ion batteries supply chains to "the top of the geopolitical agenda" for nations around the globe.

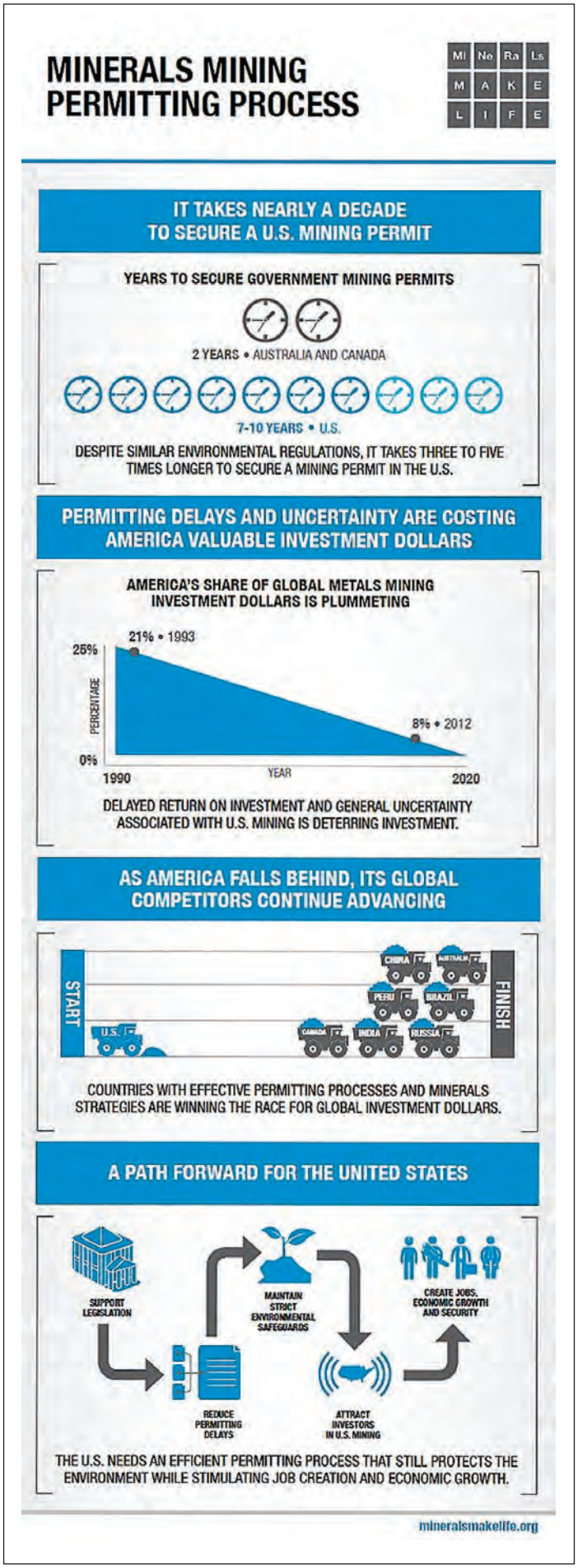
In its 2023 report, Li-Bridge outlined three major challenges to establishing a domestic lithium battery supply chain that will dramatically increase U.S. national and economic security – impatient money, uncertain permitting, and a dearth of critical minerals.

### Impatient Western money

Building an entire lithium battery supply chain from the ground up in the U.S. is going to take an enormous amount of cash and patience.

From the mines to the mineral processing plants and onto the lithium battery materials and manufacturing plants, the facilities required to meet the energy storage needs for EVs and renewable energy must be built at giga-scale.

Not only do mines and factories at this scale take massive investments, but they




also require a lot of time to design, permit, and build.

For example, a U.S. mining project that has already completed a feasibility study that demonstrates it could offer healthy returns on investment has a long runway before it is cashflow-positive – permitting a large mining project in the U.S. is expected to take at least four years, and often much longer, and then another roughly two years for development. This means that a large U.S. mining project entering permitting today would likely not begin delivering materials into the lithium battery supply chain until the end of the decade.

While lithium battery processing and manufacturing facilities tend to take less time to permit and build, they require large initial investments in research and development, time to design and build the manufacturing equipment, and a somewhat lengthy runway to scale up to full commercial production.

These long timelines, coupled with the associated risks, often dissuade Western investors that determine their cash would be better allocated in areas with proven technologies and returns in the nearer term.

Due to differences in business culture, however, Asian investors tend to take a longer-term view.

"Consequently, Asian investors fund a disproportionate share of U.S. battery-related projects. This has historically resulted in the transfer of much U.S.-based know-how and battery-related intellectual property offshore," Li-Bridge inked in its report.

The alliance believes that expanded and better-designed incentives on both the supply and demand sides of the equation will make the U.S. battery supply chain more attractive to American investors.

While the battery supply chain incentives in the Inflation Reduction Act go a long way to addressing this issue, Li-Bridge says that more must be done.

The public-private alliance recommends the following:

• **Capex incentives:** Expand incentives to offset capital expenditures for mining, processing, and manufacturing.

• **Production incentives:** Expand incentives, such as production tax credits, to offset production-related costs.

• **R&D incentives:** Quickly develop and implement tax treatment and incentives that make investment in battery research and development more attractive.

• **Demand incentives:** Expand EV sale incentives to include trucks, buses, construction, agriculture, mining, and other offroad equipment that include domestic material requirements.

• **Government procurement:** Leverage government procurement programs to support next-generation technologies and provide advanced market commitments that reduce commercialization risk.

• **Insurance pools:** Create insurance pools for battery and battery material producers to hedge against the risk of product recalls and make it easier for U.S. companies with smaller balance sheets to compete with established foreign suppliers.

"The U.S. government must take actions to enhance the expected returns on financial investments in U.S.-based lithium battery supply chain-related projects (e.g., battery materials, components, cells, or manufacturing equipment) and reduce the perception of demand uncertainty in the U.S. battery market," Li-Bridge penned in its report.

The federal government has begun to make the type of large and meaningful investments needed across the entire battery supply

chain, including investments in helping companies like Jervois Mining USA and Graphite One Inc. complete feasibility studies for domestic cobalt and graphite mines; $2.8 billion in grants for 20 projects to expand the domestic manufacturing of materials for lithium batteries; and a $2 billion to support Redwood Materials Inc.'s expansion and construction of a battery recycling and manufacturing complex in Nevada.

"In order to meet the needs of the rapidly growing EV market, the United States will need to expand battery recycling capabilities, as well as grow our domestic capacity for producing battery precursor materials," Jigar Shah, director of DOE's Loan Programs Office. "By lowering the cost of the critical materials for lithium-ion batteries using recycled materials, electric vehicles can become more accessible to lower income communities."

### Uncertain and lengthy permitting

One way to provide American lithium battery investors with more confidence and a quicker return on investment is to bring some predictability to the uncertain and lengthy permitting process in the U.S., especially when it comes to the mining projects that feed materials into the supply chain.

"Several Li-Bridge participants cited delays in their projects ranging from six months (cell manufacturing and grid energy storage projects) to a full decade (mining projects)," the battery supply chain alliance inked in its report.

Li-Bridge pointed to four major factors that contribute to long and unpredictable permitting timelines in the U.S. – opaque bureaucratic decision-making, a lack of firm permit process deadlines, inconsistent appeals process, and resistance from community groups.

The long mine permitting timelines in the U.S. is something that is weighing heavily on the minds of American auto executives scrambling to find reliable, sustainable, and preferably domestic sources of the raw materials needed to build EVs that were not required for internal combustion vehicles.

Ford Motor Company, a member of Li-Bridge, has been particularly vocal about the need for mine permitting reform in the U.S.

"Today's lengthy, costly and inefficient permitting process makes it difficult for American businesses to invest in the extraction and processing of critical minerals in the United States," Christopher Smith, the chief government affairs officer at Ford, penned in a 2022 letter to the U.S. Department of Interior.

While automakers like Ford want to ensure that the materials going into their batteries are sourced from the U.S. or allied countries, which will make the EVs they build eligible for tax credits offered to American car buyers, they also want to be able to tout the ESG credentials of their electrified models – something that would be easier to do if the mined materials came from a country with strong environmental and labor laws.

"As I've stated before, we currently get our materials for EVs from China, where environmentally responsible mining and processing is non-existent and has caused significant harm to surrounding areas and populations (yet good enough for us to use in EVs, wind turbines and other renewables)," Smith penned in his letter to DOI. "And still, there's opposition to environmentally responsible mining in the US!" the Ford exec added.

Li-Bridge's top priority for Congress is to pass mine permitting reform that will help U.S. companies secure the minerals needed to

build the low-carbon future.

This includes improving mine permitting predictability with time limits, transparency, and a lead agency that guides a harmonized permitting process.

These issues were partly addressed during the July debt ceiling negotiations that resulted in the Fiscal Responsibility Act of 2023, and there is legislation in the Senate that tackles the other permitting issues outlined by Li-Bridge.

■ *For more information on large project permit reforms in the U.S., read* ***"Will US permit a clean energy transition?"*** *on page 17 of this magazine.*

## Dearth of critical minerals

Even with a streamlined permitting process, the mining sector faces a challenge when it comes to feeding enough battery minerals and rare earths into the automotive supply chain until the first generations of EVs traveling American highways are recycled.

Based on current formulas and technologies, EV batteries alone are expected to consume around 2.4 billion lb cobalt, 1.6 billion lb of lithium, 12 billion lb of graphite, and 7.2 billion lb of nickel per year by 2040.

This equates to six times more cobalt, six times more lithium, nearly five times more graphite, and roughly the same amount of nickel produced for all sectors at every mine on Earth during 2022.

To fill this demand, a lot more battery mineral deposits must be discovered, explored, permitted, and developed into mines.

Benchmark Mineral Intelligence estimates that more than 300 new mines will need to come online by 2035 to meet the demand for cobalt, graphite, lithium, manganese, and nickel for the lithium batteries powering EVs.

This is a tall order when measured against the typical decades-long mineral discovery-to-producing mine timelines, which tend to be longer in the U.S. due to the longer permitting process.

In addition to streamlining U.S. mine permitting, Li-Bridge has seven recommendations to ensure plenty of minerals are fed into the American battery supply chain:

• **Critical minerals databases:** Expand and accelerate the creation of a national database of critical mineral resources and make this data available through an online portal and interactive map. At the same time, develop a dashboard that tracks and forecasts international supply chains.

• **Foreign partnerships:** Support prioritized access to critical mineral mines in partner countries through financial support from the U.S. International Development Finance Corp. and continue to strengthen country-level cooperation.

• **Circularity:** Establish an industry-led waste battery end-of-life program, harmonize regulations for transporting waste batteries, and support the recovery and use of domestically recycled content.

• **Trade control:** Recalibrate trade controls to encourage U.S. companies to develop high-energy-density solutions and compete for global business. Consider export controls to reduce leakage from the U.S. energy materials supply chain.

• **Critical minerals sea mining:** Conduct definitive environmental studies on critical mineral sea mining that serve to remove uncertainty regarding U.S. company participation in sea-based mineral extraction and purchasing

• **Stockpile:** Bolster the National Defense Stockpile for battery-critical minerals and materials in a manner that smooths commodity pricing cycles and does not exacerbate supply shortage or inflate raw material costs for U.S. manufacturers.

• **Infrastructure:** Invest in more clean energy generation and upgrade port and rail systems to make the U.S. lithium battery supply chain more economically competitive.

• **Industrial zones:** Select and designate special industrial zones for battery production to support the efficient clustering of battery-related operations. Steer government financial support to those zones. Implement within those zones streamlined regulatory processes recommended by industry and approved by local authorities and communities.

"The United States must work simultaneously to encourage the development of minerals and materials mining domestically and to secure the supply of raw products from reliable trading partners abroad," Li-Bridge penned in its battery materials blueprint. "An effective raw materials strategy must also include significant support for lithium battery recycling and developing a battery materials export control policy."

## Above all, an alliance

While the U.S. battery material blueprint is an important asset that offers solutions to nearly every conceivable challenge associated with building a North American lithium battery supply chain, the Li-Bridge alliance itself is the capstone.

"The public-private partnerships described in this report will be crucial to realizing that safer, cleaner future that will benefit generations of Americans to come," said U.S. Deputy Secretary of Energy David Turk.

Bringing together the pollical clout of government agencies, the brainpower of American academia and the national lab systems, and the expertise and financial wherewithal of companies that span the entire lithium battery supply chain creates a powerful alliance that can tackle the challenges much more efficiently as a group than they can individually.

This includes a united front in gaining bipartisan support in Congress and the White House for policies that support building a domestic supply chain at the pace needed to achieve America's energy transition and climate goals.

The alliance also offers the potential to create a consortium for purchasing critical battery-related minerals and materials from domestic and foreign sources that improves buying power. This would make the U.S. battery industry more competitive against countries, such as China, that have large state-backed companies and are more directly involved with materials production and purchasing.

Li-Bridge believes the formalization of its alliance, coupled with the U.S. government implementing the recommendations in its blueprint, will ensure the U.S. can capture 60% of the economic value from U.S. domestic demand for lithium batteries by 2030 and become a global power in the lithium battery industry and a major exporter of finished batteries and battery-related technology by 2050.

"By moving forward aggressively with the recommendations Li-Bridge is advancing today, the U.S. will be well positioned to unlock the benefits batteries can provide to improve our environment and our economy," said NY-BEST's Acker. DMN

STATE OF ALASKA

S&P Global Vice Chairman Daniel Yergin, (right) who coined the term "permitting pandemic," discusses the low-carbon energy transition with Alaska Gov. Mike Dunleavy.

# Will US permit a clean energy transition?

## Long permitting timelines don't fit within clean energy goals

By SHANE LASLEY
DATA MINE NORTH

**THE UNITED STATES HAS RICH DEPOSITS** of copper, cobalt, graphite, lithium, nickel, rare earths, and other mined commodities needed to build the clean energy future. The often decade-long mine permitting timeline in the U.S., however, means that many of these domestic critical mineral sources will be hard-pressed to get developed in time to help meet the climate goals laid out by the White House.

This extraordinarily long federal permitting process for large projects has global supply chains, and geopolitical experts concerned that the U.S. will find itself in economic lockdown due to a heavy reliance on the highly competitive global energy metal markets and an inability to ramp up enough production at home.

"Our country is suffering from a permitting pandemic – it leads to paralysis, lack of economic resolve, and a great deal of pain," S&P Global Vice Chairman Daniel Yergin, a highly respected authority on international energy and geoeconomics, said during a keynote address.

Yergin, a Pulitzer Prize-winning author who has written three books on international energy and geopolitics, is not the only one concerned about permitting large projects in the U.S.

Executives from across America's energy transition supply chains, and even high-level members of the Biden administration, cited the often decade-long wait for federal authorizations as the single biggest impediment to America's race to be the global leader in clean energy.

"If we are going to be successful in this competition and if we are going to take advantage of these opportunities, the jobs, we need to permit much, much quicker than we do right now," U.S. Deputy Secretary of Energy Dave Turk said during a May address to the

SOUTH32 LTD.

Aerial view of the South32 Hermosa manganese-zinc project in southern Arizona, the first first-ever critical minerals mining project in the U.S. to be accepted for the Fast-41 permitting process.

Alaska Sustainable Energy conference.

John Podesta, President Biden's senior advisor for clean energy innovation and implementation, may have put it best.

"We got so good at stopping projects that we forgot how to build things in America," he said during a May speech on infrastructure permitting reform.

## Self-inflicted permitting pandemic

When you add in the time it takes for federal and state authorizations, inevitable litigation by project opponents, and then development, it often takes the better part of two decades to go from permit applications to producing the first metal at a mine in the U.S.

"So, if we started today, we are talking about the 2040s to get something done," said Yergin.

This timeline falls outside of the Biden administration's ambitious climate goals that include having EVs making up 50% of all vehicle sales in the U.S. by 2030 and the nation achieving net-zero greenhouse gas emissions by no later than 2050.

During a May testimony before the U.S. Senate Energy and Natural Resources Committee, National Mining Association CEO Rich Nolan said the long permitting timelines in the U.S. are "completely out of step with the dramatic increases in minerals production that will be needed in the coming decades to keep up new technologies, infrastructure, manufacturing and even with the administration's own energy and supply chain goals."

And it is not only mining that is feeling the pain of the self-inflicted permitting pandemic in the U.S.

Clean energy power generation facilities, lithium-ion battery gigafactories for electric vehicles, and electrical grid expansion to accommodate an envisioned low-carbon future are subject to a similar unwieldy permitting process that mining companies must navigate to feed metals into the front end of a clean energy supply chain.

"Our self-imposed permitting delays mean lost economic opportunity, increased energy insecurity, eroding global competitiveness, and the inability to effectively address climate change," Thomas Madison Jr., an infrastructure consultant and former administrator of the U.S. Federal Highway Administration, penned in a July editorial. "Furthermore, when regulatory bottlenecks become too onerous within our borders, we inevitably increase reliance on imported materials, thereby ceding essential industries to our rivals as community-supporting American jobs and industries evaporate. Congress must immediately unwind this self-made crisis."

THOMAS MADISON

## Time is our enemy

With the entire supply chain at risk, the long permitting timeline in the U.S. is a problem that transcends the traditional divide between environment and resource development, according to Cathy Woollums, senior vice president and chief sustainability officer at Berkshire Hathaway Energy.

"Time is our enemy when we think about investment and when we think about climate," she said during a panel on investing in Alaskan sustainable energy projects.

The Berkshire Hathaway senior vice president said quick but responsible action to minimize permitting timelines is needed to fully capitalize on the clean energy transition and the economic opportunities it offers.

"It is so important to ensure that as we are moving forward on a

permitting front in a responsible way that takes consideration of the local resources and communities, and doesn't damage those, but at the same time has a limitation on time," she said.

Former Federal Highway Administrator Madison says, "America is stuck in perpetual permitting crisis" that is holding back the nation's ability to change with the times.

"There is growing bipartisan recognition that to rebuild and modernize our infrastructure and supply chains – from roads and bridges to renewable projects and the mines that supply them — we must have permitting reform," he wrote.

Nolan said mine permitting timelines in the U.S. could be significantly streamlined without compromising the rigor of the review.

The National Mining Association CEO pointed out that it only takes about two to three years to permit mines in Australia and Canada – Western countries with similar environmental, social, and governance standards as the U.S.

"The NMA believes that valid concerns about environmental protection should be fully considered and addressed but permitting processes should not serve as an excuse to trap mining projects in a limbo of duplicative, unpredictable, endless and costly review without a decision point," he testified on Capitol Hill.

## Political football

With America needing skyrocketing new supplies of minerals and metals critical to clean energy and digital technologies, mine permitting has been called off the sidelines to be a key player in Washington political football.

A push by Republican lawmakers to get some kind of mine permitting reform past the goal line for the better part of a decade has been easily defensed by Democrats, along with the help of some Republicans who did not see the topic as pressing and were unwilling to be associated with the optics of lowering environmental standards.

The ambitious clean energy goals spearheaded by the White House and supported to some degree by most policymakers on both sides of the aisle, however, has upped the urgency and support for streamlining large project permitting in the U.S.

Reforming America's permitting system has become such a hot-button topic that it has been tied to some of the biggest political moves since Biden moved into the White House, including passage of the Democrats' 2022 Inflation Reduction Act and the midnight hour legislation that prevented the federal government from defaulting on its payment obligations in 2023.

In exchange for his key vote in getting the Inflation Reduction Act passed by the Senate, Sen. Joe Manchin (D-WV) secured assurances from Majority Leader Chuck Schumer (D-N.Y.) that mine-permitting reform would be taken up.

As tens of billions of IRA dollars have been allocated to clean energy and other projects, Manchin was still waiting for a mine-permitting reform bill that would be called off the bench and onto the Senate's main playing field.

## Permitting field goal

Mine permitting reform was fielded by President Biden and House Speaker Kevin McCarthy (R-CA) during May negotiations on the Fiscal Responsibility Act of 2023, legislation that raised the debt ceiling in order to keep the U.S. out of default.

In order to gain enough bipartisan support for this legislation, Biden agreed to modest reforms that streamline permitting under the National Environmental Policy Act (NEPA), the foundation for federal permitting of large projects in the U.S.

These changes include:

**Time limits:** Environmental Impact Statements, which are required for most mining and other large projects in the U.S., must be completed within two years of the date a federal agency determines an EIS is required. Environmental Assessments for smaller projects must be completed within one year.

**Page limits:** EISs are limited to 150 pages in most cases, with a 300-page limit for extraordinarily complex projects, and EAs are limited to 75 pages. While this change may not reduce the overall size of the documents due to no appendix page limits, moving supporting data to the appendices is expected to make NEPA analysis easier for stakeholders to read and understand.

**Lead agency:** Where more than one agency is involved in the permitting decision for a project, the federal government is required to designate a lead agency to conduct any required environmental analysis. This is expected to make NEPA

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American business and policy leaders are pushing for reforms that streamline the arduous permitting process for the large projects needed to build the envisioned clean energy future in the United States.

permitting less complex for applicants and streamline the process by avoiding duplicated efforts.

**NEPA revisions:** The core requirements of NEPA would be amended, primarily to limit the obligation to consider environmental impacts to those that are "reasonably foreseeable." This will prevent delays related to assessing speculative impacts or those not directly related to the project being permitted.

Minerals Make Life, a National Mining Association outreach group, says that designating a lead agency for mine permitting may be the single most impactful part of the negotiated reforms.

"This means one federal agency will serve as the coordinator of all other federal agencies conducting environmental reviews and that they will all work to prepare a single environmental review document, which is focused on actual environmental impacts and mitigation," the mining group wrote in a June blog. "This makes so much sense that it leaves many wondering why it wasn't done sooner."

## Going for the touchdown

While these and other NEPA reforms included in the Fiscal Responsibility Act are considered a field goal by advocates for mine permitting reform, they are not the touchdown many see as required to ramp up domestic mineral production at the pace needed to win the climate change Super Bowl.

"Targeted changes in the debt-ceiling deal – such as tightening the scope and timetable for environmental reviews – are important steps forward. But we shouldn't declare 'mission accomplished' just yet. Half-measures won't deliver the change we need," Madison wrote.

A pair of bills introduced to the Senate in May by Sens. Shelley Capito, R-W.Va., and John Barrasso, (R-Wyo.) – RESTART Act and SPUR Act – have the provisions needed to get large project permitting reform in the U.S. across the goal line.

"The two bills Senator Barrasso and I are introducing fix this broken system with substantive changes that cut red tape, modernize and streamline the permitting process, and prevent endless delays that have plagued job-creating projects across the country," said Capito, who introduced the RESTART Act.

While several of the permitting issues addressed by these bills were covered during debt ceiling negotiations, a couple of key issues that hold back or halt large projects were not.

The biggest issue is lawsuits that are often not filed until a project is about to break ground in order to maximize delays.

The SPUR Act includes provisions that would require lawsuits

against permits and licenses for mining projects to be filed within 60 days, and the RESTART Act would require courts to process challenges and issue a final judgment within 180 days.

The SPUR Act addresses another big challenge that has come up in recent years, the withdrawal of federal lands where mining projects are being advanced.

Barrasso's bill requires a congressional resolution of approval for any U.S. Department of Energy mineral withdrawal in excess of 5,000 acres. It also prohibits the Secretary of Interior from imposing a moratorium on issuing leases, claims or permits for mining on federal lands.

"We need to lower prices for American families and unleash American energy. The way to do that is to impose strict deadlines and stop endless litigation," the Wyoming senator said. "We must also block the administration from hijacking the permitting process to kill worthy projects."

## Fast-41 for the win

Despite all the political football, the U.S. already has a mechanism in place that, if fully utilized, would achieve most of the goals of mine permitting reform and renewable energy advocates, alike.

This mechanism, known as Fast-41, was first established while Biden was Vice President in 2015 to improve the timeliness, predictability, and transparency of federal domestic infrastructure projects.

Short for Title 41 of the Fixing America's Surface Transportation Act, Fast-41 established the Federal Permitting Improvement Steering Council (FPISC), a federal entity that offers a one-stop-shop capable of coordinating permits across different federal agencies, thereby streamlining and shortening the overall process for large infrastructure projects that are eligible for the program.

In 2020, certain mining projects that supply the materials needed for the energy, communication and transportation infrastructure in the U.S. became eligible for Fast-41. The Fiscal Responsibility Act of 2023 added energy storage to the projects eligible for the streamlined NEPA review process offered by this program.

A bill to amend and make permanent the Fast Act to improve the federal permitting process was introduced to the Senate in July by Dan Sullivan, R-Alaska, Rob Portman, R-Ohio, Kyrsten Sinema, D-Ariz., and Joe Manchin, D-W.Va.

"FAST-41 improved the federal permitting process to promote expansion, economic growth, and the hiring of American workers right here at home," said Portman. "We need to make this program permanent, apply it to more federal projects to ensure they get done on time and under budget, and expand the authority of the Permitting Council to see to it that those things happen."

The Federal Permitting Reform and Jobs Act introduced by the bipartisan group of senators would:

- **Make Fast-41 permanent** by eliminating a seven-year sunset clause for the federal program.
- **Expand FAST-41 benefits** to include infrastructure projects sponsored by or on land owned by tribes, Alaska Native corporations or Native Hawaiian organizations, regardless of size, and the council's annual best practices report would be required to address how to improve engagement with tribal stakeholders.
- **Set a two-year goal for permitting** Fast-41 eligible projects. Current law requires the permitting council to create template permitting timetables for various types of projects, which agencies must use to set deadlines for permitting covered projects unless they can explain why additional time is needed.
- **Encourage permitting coordination** by having federal agencies prepare one joint environmental impact statement, whenever possible, to enhance coordination and transparency among the agencies.
- **Improve FPIC's day-to-day operations** by reducing paperwork burdens, improving information-sharing, and giving the permitting council more clarity for internal deadlines.

"If we are going to grow our economy, build out vital infrastructure, and provide good-paying jobs for hard-working Americans, it's critical that we provide more certainty in the permitting process and continue to improve how we build projects," said Sullivan. "Making the FAST-41 reforms permanent, expanding project eligibility, and speeding up our burdensome permitting process through better coordination are bipartisan reforms that will help ensure the money we spend today on infrastructure puts Americans to work and benefits Alaska and the country now, when we need it most."

These reforms could help reverse the permitting pandemic observed by Yergin and Podesta so that America forgets how to stop large projects and gets good at building things again. CMN


S&P Global predicts that there will be a 3.5 billion to 21.8 billion metric ton shortage of copper by 2035.
ADOBE STOCK

# Copper is critical to almost everyone

## USGS ignores calls by businesses, lawmakers to elevate status

By SHANE LASLEY
DATA MINE NORTH

**EVERYONE AGREES THAT HISTORICALLY** enormous quantities of copper are essential to wiring a world in which low-carbon electricity delivered via powerlines supplants fossil fuels pumped through pipelines as the energy solution of choice. The federal entity charged with compiling the list of minerals critical to the United States, however, disagrees with nearly every company, organization, and person associated with the clean energy supply chain on the criticality of the conductive metal.

The case for copper's criticality is backed by commodity analysts that predict global copper production will need to double by 2035 to meet demands driven by global net-zero emission goals. Building that level of capacity in just 12 years, while at the same time not losing any output from existing mines, is a highly unlikely scenario.

In its most optimistic forecast, S&P Global estimates that annual production from global mines will be 1.6 million metric tons (3.5 billion pounds) short of meeting copper demands in 2035. In its most pessimistic scenario, this copper shortage is a staggering 9.9 million metric tons (21.8 billion lb).

"The challenge is that if current trends continue ... there's a huge gap," S&P Global Vice Chair Daniel Yergin said upon the release of the copper analysis. "And even if you put on your roller skates and your jet burner [to realize optimistic supply growth], and everything goes right, there's still a gap, because it's enormous. And it's

important to recognize that now, not in 2035."

This warning follows a 2020 World Bank report that estimates that the green energy transition alone will require approximately 550 million metric tons (1.1 trillion lb) of copper over 25 years and a 2022 report and Goldman Sachs declaring copper as the "new oil" due to the critical role it plays in the clean energy future.

Despite the growing consensus that it is going to require extraordinary measures to ensure that there is enough copper to achieve global net-zero carbon emission goals, the U.S. Geological Survey has remained steadfast in its refusal to add this metal to America's critical minerals list.

Fielding a question on copper's criticality from mining executive Rick Van Nieuwenhuyse during an Arctic critical minerals summit in Washington, DC, USGS Director Dave Applegate said his agency's determination that copper is not critical is based on a supply risk assessment.

"There are many essential minerals, and copper absolutely is an example of that," he said.

The USGS, however, does not see enough risk for supply chain disruptions to elevate copper onto the critical minerals list – a risk assessment that seems to ignore the forecasts that demand will outstrip supply over the next two decades.

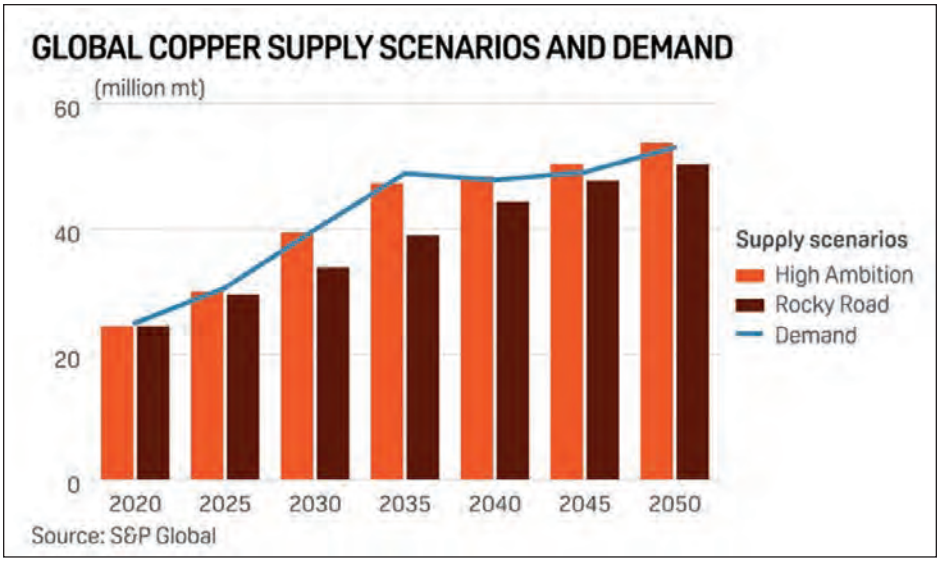
DAVID APPLEGATE

With it becoming increasingly apparent that it is going to take an act of Congress to elevate copper onto the US critical minerals list, a group of Washington lawmakers have decided to do just that.

In June, Congressman Juan Ciscomani, R-Ariz., introduced the Copper is Critical Act, a bill that would elevate copper's criticality status – with or without USGS consent.

## "It's obvious" copper is critical

The debate over copper's criticality has been brewing ever since the USGS unveiled its updated list of critical minerals in 2022. Copper was nowhere to be found between the aluminum and zinc on this list of 50 minerals and metals deemed critical to the U.S.




S&P GLOBAL

Given the enormous quantities of copper needed to wire the wind turbines, solar farms, electric vehicles, and increased electrical transmission lines that will deliver the envisioned low-carbon future, this omission was a surprise to many mining executives and analysts.

This includes billionaire mining magnate Robert Friedland, who contends that adding the red energy metal to the list is essential to achieving the White House's climate goals.

"It has to be, it's obvious," he said in response to a question on copper criticality during a June interview on Bloomberg TV interview. "America hasn't developed a mine of consequence for 40 years. The mining of copper is "absolutely critical."

Research analysts at Goldman Sachs contend that copper is so "critical to moving the global economy toward net-zero emissions" that they have deemed this metal the "new oil."

In an updated version of their 2021 "Copper is the new oil" report, Goldman Sachs analysts wrote, "The copper market is unprepared for this critical role."

Much like S&P Global, Goldman Sachs foresees green energy demand outstripping the mining sector's ability to supply copper over the next decade.

Based on the expected large supply gap and increased competition that sees copper supplanting oil in the realm of global geopolitics, the Copper Development Association decided to get a second opinion on copper's criticality.

"Because USGS data was considerably out of date upon the release of the 2022 Critical Minerals List, and the risks to copper from imports has increased dramatically, we engaged an analyst to update copper's supply risk score with the most recently available data to 2022," said Copper Development Association President Andrew Kireta, Jr.

Based on this analysis, which mimicked USGS methodology, the CDA concluded that copper has hit the "critical" echelon and called for the electrical conducting metal to be included in the U.S. critical minerals list.

ANDREW KIRETA JR.

"Copper is and always has been critical to our economic and national security but now to the clean energy transition as well," Kireta added. "As copper now meets the threshold for inclusion based on the very latest available data, we need to act immediately to enable the copper industry to provide the essential inputs that copper provides to our national defense and economic security."

## Critical copper coalition

A large critical copper coalition that includes U.S. lawmakers from both sides of the aisle and 75 trade associations and unions representing essentially the entirety of the American economy joined CDA in petitioning the USGS to elevate copper's criticality status.

This coalition includes many organizations that do not typically advocate for mining, such as the Electric School Bus Coalition, National Mining Association, United Association of Plumbers and

Copper cables used for electrical transmission.
ADOBE STOCK

Pipefitters, and Zero Emission Transportation Association.

This seemingly unlikely advocacy group, however, did not mince words in their support of immediately adding copper to the U.S. critical minerals list.

"We, the undersigned users, consumers, partners and supporters of the copper industry write to urge you to formally designate copper as an official USGS Critical Mineral without delay," the coalition penned in a Feb. 2 letter to U.S. Secretary of Interior Deb Haaland.

Six U.S. senators – Kyrsten Sinema (I- AZ), Mike Braun (R-IN), Mark Kelly (D-AZ), Joe Manchin (D-WV), Mitt Romney (R-UT), and Raphael Warnock (D-GA) – were equally emphatic that the Department of Interior reexamine copper's criticality.

In their own letter to Haaland, the senators pointed to a recent S&P Global report that forecasts a "chronic gap between worldwide copper supply and demand projected to begin in the middle of this decade will have serious consequences across the global economy and will affect the timing of Net-Zero Emissions by 2050".

"By recognizing copper as a critical mineral, the United States' federal government can more effectively ensure a secure and reliable supply of domestic copper resources in the years to come at all points of the supply chain including recycling, mining, and processing," the senators wrote in the letter to Haaland.

## Debate heats up

USGS, which falls under Halland's Interior Department, held steadfast that copper does not belong on the list of 50 minerals critical to the U.S.

"While copper is clearly an essential mineral commodity, its supply chain vulnerabilities are mitigated by domestic capacity, trade with reliable partners, and significant secondary capacity," Applegate penned in a May letter to U.S. Sen. Kyrsten Sinema, I-Ariz. "As a result, the USGS does not believe that the available information on copper supply and demand justifies an out-of-cycle addition to the list at this time."

Applegate's letters to Sinema and other senators petitioning for copper's criticality elicited an uncharacteristically heated response from Kireta.

"Despite clear data showing that copper's supply risk score is now above the threshold for automatic inclusion on the 2022 Critical Minerals list, USGS sent well-crafted letters to a bipartisan group of congressmen and senators filled with misleading arguments that were not part of its own official 2022 methodology, or consistent with the spirit or letter of the law, to justify a decision to forego immediately adding copper to the list," said the CDA president. "This decision was made even though Secretary Haaland has the authority given to her by statute to add copper to the list, without waiting for the next update in three years."

Arizona Rep. Ciscomani and members of the Western Caucus decided that if the USGS were unwilling to put copper on the critical minerals list, they would let Congress take up the matter.

"Designating copper as a critical mineral will open up more doors to creating a dependable domestic stockpile of the material," he said.

The Copper is Critical Act introduced by Ciscomani proposes that copper be deemed critical, period.

"We must ensure that America's manufacturers and supply chains have ready, reliable, economic access to copper to meet the growing demand and policy goals for a cleaner electrical grid, a lower carbon economy, and a strong and resilient defense sector," said Kireta. "CDA calls upon members of Congress to not accept USGS' decision lightly and to undertake all means and measures to address this ill-conceived and unfounded decision."

### DOE elevates copper's status

As the USGS continued to fend off pressure to elevate copper's criticality, the U.S. Department of Energy included the red metal on its list of critical minerals.

Copper's critical inclusion came in DOE's "Critical Materials Assessment 2023", a July report detailing the department's analysis of materials essential to electric vehicles and renewable energy infrastructure.

"As our nation continues the transition to a clean energy economy, it is our responsibility to anticipate critical material supply chains needed to manufacture our most promising clean energy generation, transmission, storage and end-use technologies, including solar panels, wind turbines, power electronics, lighting, and electric vehicles," said Alejandro Moreno, acting assistant secretary for DOE's Office of Energy Efficiency and Renewable Energy.

CDA was quick to commend DOE for being the first U.S. agency to join the European Union, Japan, India, Canada, and China in recognizing copper's critical role in a world transitioning to clean energy and transportation.

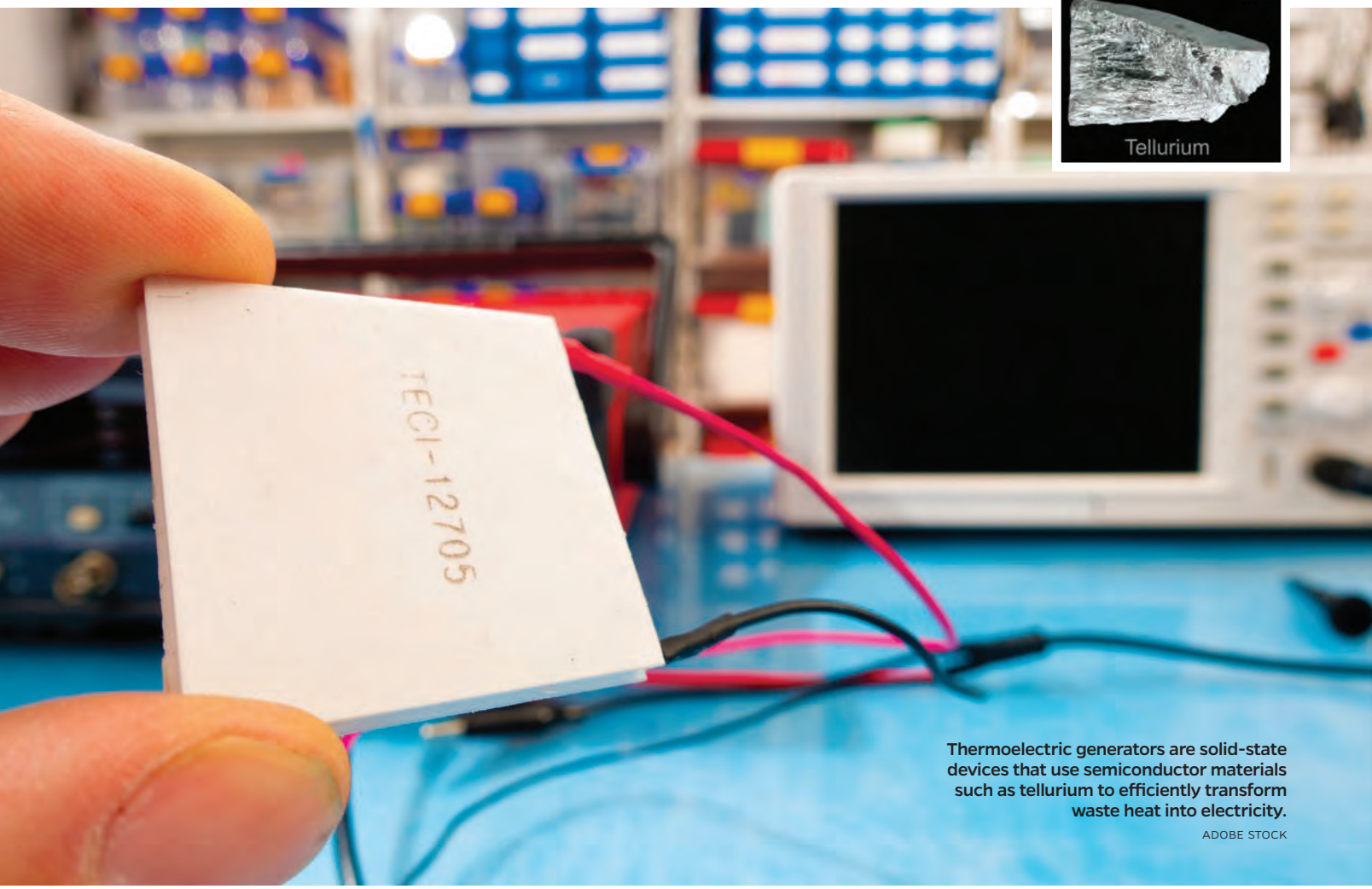
"Copper is a major contributor to U.S. economic and national security, and with copper demand projections doubling by 2035, primarily due to plans for the clean energy transition, electrification, and clean water infrastructure," said Kireta. "The nation would be defenseless without electricity and copper's vital role in its generation, transmission, and distribution."

DOE agrees with USGS's assessment that there is a diverse and relatively low-risk global supply of copper, but expressed concerns that falling ore grades will impact future supply and growing competition on the demand side. It is this longer-term view that prompted the Energy Department to deem copper as critical.

"Ultimately, identifying and mitigating material criticality now will ensure that a clean energy future is possible for decades to come," Moreno added.

While CDA is pleased to see DOE's recognition of copper as critical to America's energy transition, the copper mining sector association is continuing to advocate for copper's inclusion on USGS's official list, which has implications when it comes to streamlining permitting and federal funding and tax credits.

"The U.S. should do all it can to protect and promote our domestic copper industry," Kireta said.This is a tall order for mining companies, which are already falling behind. DMN




Thermoelectric generators are solid-state devices that use semiconductor materials such as tellurium to efficiently transform waste heat into electricity.

ADOBE STOCK

# Tellurium: secret clean energy ingredient

## Rare metalloid used in American-made solar, batteries are next

By SHANE LASLEY
DATA MINE NORTH

**FROM PROMISING SOLID-STATE** battery technology that could eliminate range anxiety for electric vehicle owners to solar panels and thermoelectric devices that transform sunshine and heat into low-carbon energy, tellurium is emerging as a secret ingredient of the clean energy future.

"It has flown largely under the radar, even though it's essential for cadmium-telluride solar panels and new lithium-tellurium batteries that could revolutionize energy storage," said Tyrone Docherty, president and CEO of First Tellurium Corp., a company advancing tellurium exploration projects in the United States and Canada.

One of the reasons tellurium has gone largely unnoticed is that cadmium-telluride (CdTe) solar technology has not gained international acclaim, only accounting for around 5% of the photovoltaic (PV) solar panels installed globally. In the U.S., however, these thin-film panels are much more popular, making up around 55% of new installations, according to the U.S. Department of Energy's 2023 Critical Materials Assessment.

This outsized popularity in the U.S. is due to the success of Ohio-based First Solar Inc., the world's largest manufacturer of CdTe solar panels.

Seeking to bolster this homegrown technology, the U.S. Department of Energy is investing $20 million into the Cadmium Telluride

Accelerator Consortium, an initiative seeking to increase the efficiency of CdTe cells and lower the cost of these thin-film panels and the materials that go into them.

DOE foresees shortages of the tellurium as the popularity of this solar technology rises.

"Without significant expansion of the tellurium supply capacity, shortages of Te could occur in the short term (2025) and are likely in the medium term (2025-2035)," the Energy Department penned in its 2023 Critical Minerals Assessment.

To help fill shortfalls of tellurium needed for solar panels and other clean energy technologies, First Tellurium is exploring two North American mineral exploration projects – Klondike in Colorado and Deer Horn in British Columbia – that could offer North American supplies of this critical metalloid.

## Heavy First Solar investments

The demand for tellurium is growing alongside First Solar, which has already invested heavily into its manufacturing capacity in the U.S., plans to invest roughly another $1.2 billion to expand its capacity to produce American-made solar modules above 10 gigawatts by 2025.

"This investment is an important step towards achieving self-sufficiency in solar technology, which, in turn, supports America's energy security ambitions, its deployment of solar at scale, and its ability to lead with innovation," said First Solar CEO Mark Widmar.

Toward achieving these lofty ambitions, First Solar announced in August that it will build a $1.1 billion plant in Louisiana capable of producing 3.5 GW of CdTe solar panels per year.

Additionally, the company is investing $185 million to upgrade and expand its three CdTe solar panel plants in Ohio, the largest vertically-integrated complex of its kind in the Western Hemisphere. First Solar anticipates that its American plants will have the capacity to produce 14 GW of solar panels per year by the end of 2026.

By the time the Louisiana plant comes online, First Solar will have spent more than $4 billion in U.S. solar manufacturing and research and will employ more than 3,000 people in four states.

"We are investing in America's future," said Widmar.

First Solar is also working alongside DOE as a private sector partner in the Cadmium Telluride Accelerator Consortium, a three-year collaboration to lower the cost, increase the efficiency, and expand American production of CdTe solar technology.

"While already enjoying great success in the marketplace, recent scientific developments make it clear that CdTe PV has significantly more potential for dramatically higher module efficiency, lower cost, increased lifetime energy, and more rapid production," said Martin Keller, director at DOE's National Renewable Energy Laboratory, which is heading the consortium.

DOE hopes this consortium will ensure that America remains the leader in CdTe thin film solar cells that will bolster the economy while achieving the Biden administration's clean energy goals.

"As solar continues its reign as one of the cheapest forms of energy powering our homes and businesses, we are committed to a solar future that is built by American workers," said Energy Secretary Jennifer Granholm.

RIO TINTO

Copper telluride filter cake, the finished product from Rio Tinto's Kennecott tellurium plant, will be refined into the tellurium needed for solar panels and other specialty uses.

>> *"It has flown largely under the radar, even though it's essential for cadmium-telluride solar panels and new lithium-tellurium batteries that could revolutionize energy storage."*

*–First Tellurium CEO Tyrone Docherty*

## Green energy symbiosis

DOE's vision of more homes and businesses being powered by American-made CdTe solar panels will require significant new tellurium sources over the next decade.

Tellurium, however, is an extremely rare metalloid that falls in a grey area of the periodic table between metals such as aluminum and tin and non-metals like carbon and phosphorus.

"Most rocks contain an average of about 3 parts per billion tellurium, making it rarer than the rare earth elements and eight times less abundant than gold," the U.S. Geological Survey penned in a report on the critical metalloid.

While tellurium may be one of the scarcest of the elements, a little bit goes a long way. Out of the 600 metric tons produced globally during 2022, about 40% (240 metric tons) went into CdTe solar cells, 30% (180 metric tons) went into thermoelectric devices capable of transforming waste industrial heat into clean electricity, and the balance (180 metric tons) was primarily used in alloys and the production of rubber.

Most of the tellurium produced was recovered as a byproduct of refining copper.

This is creating a green energy symbiosis where the same climate goals that are increasing the need for tellurium are also powering the demand for the copper that goes into the electrical cables that link CdTe solar panels together and then to the grid.

China and Russia, however, account for roughly two-thirds of the global tellurium production.

"Tellurium supply risk is expected in the

short and medium terms largely due to its strong codependence with copper production markets, low producer diversity with the majority of the refined Te coming from China, and potential for demand to exceed supply unless tellurium production increases," according to DOE.

## Delivering domestic tellurium

To help alleviate some of the tellurium supply risks to America's rapidly expanding CdTe solar sector, global metals and mining company Rio Tinto invested approximately $2.9 million to build a plant capable of recovering roughly 20 metric tons of this semiconductive metalloid at a Utah refinery that processes copper concentrates produced at its Kennecott Mine.

"We are proud to deliver a new domestic supply of tellurium to support the manufacturing of solar panels and other critical equipment here in the United States," Rio Tinto Copper CEO Clayton Walker said upon the mid-2022 start-up of this facility.

The tellurium recovered from Kennecott is being refined by 5N Plus, a leading global producer of specialty semiconductors and performance materials.

Most of the tellurium recovered by Rio Tinto and refined by 5N Plus is going into CdTe cells being manufactured by First Solar.

"Rio Tinto's decision to invest in tellurium is a win for responsibly-produced, American solar," said First Solar Chief Manufacturing Operations Officer Mike Koralewski. "We're thrilled that tellurium from Kennecott will play a role in powering our country's transition to a sustainable energy future."

With byproduct copper production of tellurium "nearing saturation in every country other than China," DOE says that the U.S. may need to look for alternative supplies of this critical semi-metal.

## First Tellurium hunt

First Tellurium is exploring some of North America's most promising tellurium supply alternatives on its properties in Colorado and Canada's British Columbia.

"It's clear that North America is going to need a lot more tellurium," said Docherty. "This is why we're on the hunt for new tellurium projects in addition to Deer Horn and Klondike."

First Tellurium's Klondike property in Colorado was previously owned by First Solar, which was looking for a secure domestic supply of the thin-film solar panel ingredient as it was ramping up manufacturing in the U.S.

When the solar manufacturing company decided to forego its mining venture, First Tellurium picked up this property where samples with as much as 3.3% tellurium, along with 33.7 grams per metric ton gold and 364.8 g/t silver, were collected.

"The Klondike property has by far the highest tellurium grades in rock samples of the hundreds of prospects and mines we examined in the U.S. and Canada from 2006 to 2011," said John Keller, the previous mineral exploration manager for First Solar and a current consultant to First Tellurium. "Some samples at Klondike were an order of magnitude higher in tellurium grade than any others we collected in the U.S. or in Canada."

The most advanced project in First Tellurium's portfolio, however, is Deer Horn.

Located in western BC, Deer Horn hosts 93,000 kilograms of tellurium, along with 100,000 ounces of gold and 3.3 million oz of silver, in the combined indicated and inferred resource categories, making it the only gold-silver project in North America with an industry-compliant NI 43-101 tellurium resource.

UNIVERSITY OF BRITISH COLUMBIA OKANAGAN

Quasi-solid-state lithium-tellurium battery cells being tested at UBC Okanagan's Advanced Materials for Energy Storage Lab.

This property hosts a number of other targets enriched with bismuth, copper, molybdenum, tungsten, and zinc. Metals that have been deemed critical in Canada and the U.S.

"Canadian and U.S. governments are really pushing new strategies and funding initiatives to address the problem of critical mineral supplies," said Docherty. "North America is just too dependent on foreign sources for the critical metals required for clean energy, defense and other essential needs."

## Solid-state tellurium batteries

In addition to exploring for new North American tellurium sources, First Tellurium is investigating new green energy uses for this critical metalloid.

This includes what is considered to be a key technology to the widespread adoption of e-mobility, a battery that lasts longer, charges faster, and is safer than the lithium-ion batteries currently being installed in EVs.

Earlier this year, a research team at the University of British Columbia Okanagan published a study that shows adding a dash of tellurium enhanced the lifespan, charging time, safety, and capacity of existing lithium battery technologies.

"All-solid-state, lithium-tellurium batteries enable higher energy output with an improved safety rating inside a smaller form-factor, thereby expanding its possible applications," said Jian Liu, principal's research chair in energy storage technologies at UBC Okanagan.

Fenix Advanced Materials, a BC-based company that specializes in ultra-high purity metals for the clean energy sector, is supplying the UBC research team with high-quality tellurium derived from Deer Horn.

"The high purity of the tellurium along with the mineral's overall attributes makes it ideal as a rechargeable battery material," said Liu.

Using this material, the team developed a quasi-solid-state lithium-tellurium test battery with a flexible gel polymer electrolyte that allows lithium ions to move between the lithium anode and the tellurium cathode.

"It's possible that tellurium could have the largest single impact on future battery technology over any other critical mineral," said Docherty. "Its properties are unique, the demand is increasing, and America's mandate is to source tellurium at home and become less reliant on China is changing the landscape." DMN




WIKIMEDIA COMMONS; ADAM RĘDZIKOWSKI

**Battery-grade cobalt sulfate is a high-purity pinkish-red crystalline material with very low levels of impurities. It is suitable as a raw material for precursor cathode active materials used in the manufacture of lithium-ion batteries.**

# Oncoming cobalt surplus may ravage prices

## While Glencore stockpiles, China may not be so benevolent

By A.J. ROAN
DATA MINE NORTH

**STILL OVERSHADOWED BY LITHIUM** but no less significant, cobalt falls within a unique category as a critical mineral not only for its properties but also for its controversial supply.

As a fundamental component necessary for nickel-cobalt-manganese (NMC) lithium-ion batteries, cobalt warranted its place as a critical mineral vital to the zero-carbon transition due to the necessity of those batteries to power a clean, emission-free future.

Its critical uses, however, go far beyond EV batteries. For example, cobalt is also used in airbags; catalysts for the petroleum and chemical industries; cemented carbides (also called hard metals) and diamond tools; corrosion- and wear-resistant alloys; drying agents for paints, varnishes, and inks; dyes and pigments; ground coats for porcelain enamels; high-speed steels; magnetic recording media; magnets; and steel-belted radial tires, to name a few.

Much like other widely used minerals, if supply ever becomes endangered, many of those industries that rely on cobalt will be unable to deliver.

Nevertheless, battery metal markets are booming on the back of rising EV sales, so supply may be pinched, but its constant demand implies it's not going anywhere.

Supply chain issues and a global rush to secure supplies have skyrocketed battery metal prices over the last couple years, and if battery metals remain expensive, a decade-long freefall in lithium-ion battery prices might come to a temporary halt.

Before the transition truly got underway, cobalt was by far the most expensive battery metal – its recorded highest-ever price was $95,250 per metric ton in 2018.

Last year, a metric ton of lithium carbonate, 1,000 kilograms, climbed to as high as $80,000, up from around $6,500 at the beginning of 2021.

However, the price of lithium has quickly fallen to more reasonable prices, perhaps due to advancements in battery technology, among other things. Comparatively, cobalt had its spike early and appears to have evened out.

These price swings are impacting lithium battery prices and, as a result, the EVs they power.

According to Visual Capitalist, based on the experience or learning curve, also known as Wright's Law, lithium-ion battery cell costs are predicted to fall 28% for every cumulative doubling of units produced.

Previously determined to accurately predict the price decline in automobiles, so far, reported battery prices have been in line with modeled forecasts utilizing Wright's Law. With the battery pack being the most expensive part of an electric vehicle, consequently, sticker prices of EVs should fall with the declining cost of batteries.

However, the infographic specialist predicted the cost of lithium-ion batteries to fall to around $100 per kilowatt-hour by 2023 – the price point at which EVs are as cheap to make as gas-powered cars – however, according to BloombergNEF, the average cost per kilowatt-hour in 2023 actually climbed to $151 from the average of $141 in 2021.

Whether the prediction model was wrong or the volatility of the market has created an anomaly, the fact of the matter is EVs aren't there yet, but the demand being driven by them is.

## Cobalt overload

Despite its listed criticality, current metrics show this blue mineral is on track to break ahead of the impending demand.

According to mining titan Glencore, surging cobalt supply from Indonesia and Africa is forecast to outpace EV battery demand, generating large surpluses over the next couple of years, which will keep prices of the metal under pressure.

Shining a spotlight on the deteriorating outlook, Glencore said it would consider adding to its cobalt stockpiles and cut production to support prices.

Falling as low as $13.08 a pound in June, some of the lowest prices cobalt has seen in years and an almost 65% drop from prices seen just a month earlier, due to weak demand and growing supplies from Indonesia – the second largest producing country next to the Democratic Republic of Congo – the cobalt producer is confident it can hold out.

"There is still surplus in the market," said Glencore CEO Gary Nagle. "Taking action is something we have done before and it is something we will consider in the future … (It) could be lower production or stockpiling for a period of time or a combination."

Easily the largest producer of cobalt globally, accounting for an average of nearly 20% of global production, if Glencore intends to keep prices competitive, it will probably happen.

Supplying roughly 43,800 metric tons of cobalt in 2022 and 21,700 metric tons for the first half of 2023, according to data from Darton Commodities, Glencore accounted for 23% of global mined cobalt supplies of more than 187,000 metric tons last year, when the market recorded a near 17,000 metric ton surplus.

"Electric vehicle use of cobalt is very strong and the forecast remains very strong," added Nagle. "Aerospace and defence are also very strong."

He also added that the use of cobalt in consumer goods had been weak but was picking up.

Surpluses are expected to remain a feature of the cobalt market as producers in Indonesia ramp up production and exports from China's CMOC Group's Tenke Fungurume mine in the Democratic Republic of Congo reach the market after a one-year stoppage caused by a dispute with the government (in 2021, Tenke Fungurume supplied 10% of the world's cobalt).

"The market is bracing itself for the release of over 15,000 tonnes of cobalt in hydroxides from CMOC's Tenke Fungurume mine," said

GLENCORE

Glencore is considering cutting back on cobalt production or stockpiling the battery metal to support prices.

Macquarie Group analyst Jim Lennon.

Lennon expects cobalt surpluses to amount to 8,600, 10,200, and 10,400 metric tons this year, 2024, and 2025, respectively.

"In total, there are a large number of DRC mine projects which could add 50,000 tonnes a year to supply by 2027," he added.

If plans by mainly Chinese firms to increase capacity in Indonesia are executed successfully, the Australia-based financial firm reckons cobalt supplies from the world's second-largest producer will jump to 83,800 metric tons in 2027, more than 30% of the total from 10% in 2022.

Although identified as a critical mineral by the United States and the European Union, Chinese battery producers have reportedly switched from the NMC battery chemistry to the cheaper lithium iron phosphate (LFP) batteries, which means cobalt demand is expected to grow less than previously predicted.

"To some extent substitution and the move to higher nickel and lower cobalt batteries (to boost the driving range) has been offset by higher electric vehicle sales," said Bank of America analyst Michael Widmer.

## DRC is not ESG

As demand for batteries sees exponential growth and the world seeks emission-free energy alternatives, batteries are an essential component of our future.

According to the World Economic Forum, it projects that the "production of minerals such as graphite, lithium and cobalt could increase by nearly 500% by 2050 to meet growing demand for clean energy technologies."

To oversee the standards of battery metals, in particular, cobalt, the Global Battery Alliance initiated the Cobalt Action Partnership.

With an estimated 50% of the world's cobalt mine reserves located in DRC, artisanal and small-scale mining has, however, been undeniably tied to human rights violations, child labor, exploitation, and forced labor – i.e., modern slavery – in this country, and this operation.

Without a spoon full of sugar, according to the Governance and Social Development Resource Centre, the Global Slavery Index (GSI) estimates there are some 45 million people in some form of modern slavery on average each year.

In the case of DRC, the GSI 2016 reported an estimated 873,100 people were enslaved, which ranked the African nation as number nine out of 167 countries for slavery.

In contrast, the 2023 GSI ranked DRC as number 97 out of 160 countries globally, a significant improvement in just seven years and optimistically a hopeful change from the spotlight being shone on it.

With earlier hits to its sales from Tesla's questionable procurement of cobalt from DRC to power its EVs, electric vehicle manufacturers determined that consumers would most likely be unhappy if they were driving cars enabled by slavery.

Thus, in 2020-2021, the GBA convened a comprehensive global stakeholder consultation process on the artisanal and small-scale mining cobalt framework as part of the Cobalt Action Partnership to immediately and urgently eliminate child and forced labor from the cobalt value chain, contribute to the sustainable development of communities, and respect the human rights of those affected.

Whether or not this action partnership had a direct influence or other factors were at play, climbing 90 ranks in seven years is a win for clean energy, but more so a win for human rights.

## North American domestic supply

While efforts to curtail abuses in Africa were and are ongoing, the U.S., Canada, and other allied nations have been seeking ways to provide this valuable material domestically.

Toward this goal, cobalt hopefuls may have gotten a clue through a town in Ontario, Canada.

Aptly named Cobalt, this town is about 260 miles (418 kilometers) north of Toronto and is known for its rich stores of silver-cobalt mineralization once produced there.

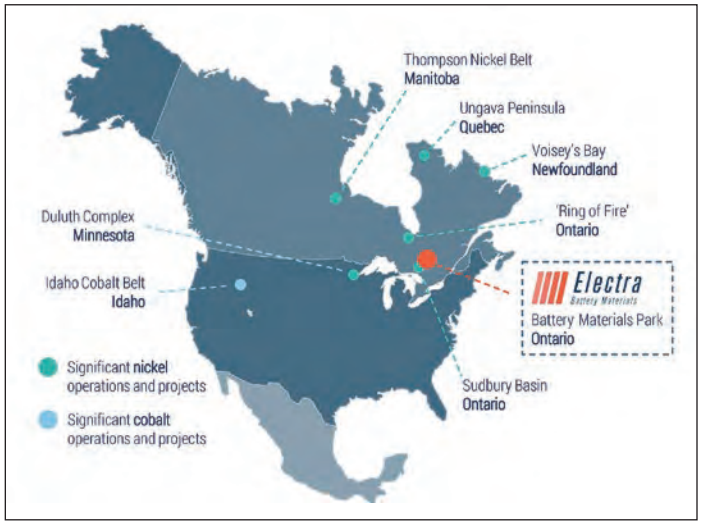
Coming a long way since its First Cobalt days, the now-named Electra Battery Materials was founded in 2017 and has quickly gained traction as a likely leading provider of the critical minerals and metals that will fuel the zero-carbon future.

Starting with the acquisition of the Yukon cobalt refinery, a fully permitted processing facility in Ontario that operated from 1996 until 2015, over the ensuing years, Electra has steadily advanced into an operation that is capable of producing roughly 5,000 metric tons of battery-grade cobalt sulfate per year.

Located less than 400 miles (640 kilometers) from Great Lakes manufacturing towns such as Detroit and Buffalo, this rail-accessible refinery has garnered strong interest from battery and automotive manufacturers seeking a secure and sustainable supply of this controversial battery metal.

With the first mover advantage of the first cobalt sulfate refinery in North America, Electra has quickly carved itself a position in the low-carbon energy and transportation transition for years to come. And with plans to expand into alternate recycling technologies, such as solvometallurgy, as well as black mass material recovery, Electra is well on its way to helping the West break away from its reliance on the East.

ELECTRA BATTERY MATERIALS CORP.




**Electra's refinery and North American nickel and cobalt projects.**

To further cement its growing space in the North American cobalt domain, in September 2022, Electra caught the attention of one of the world's largest lithium-ion battery companies, LG Energy Solution, and immediately struck back-to-back deals to source battery-grade cobalt and lithium from the province.

Aimed at securing the materials needed for the batteries powering North America's rapidly growing EV market, LG Energy Solution agreed to buy battery-grade cobalt from Electra Battery Materials Corp.'s emerging battery materials park in Ontario and battery-grade lithium hydroxide from the Thunder Bay facility that Avalon Advanced Materials Inc. is developing in the province.

"As we have recently announced our mid- to long-term strategy to focus on North America, the fastest growing EV market, these partnerships serve as a crucial step towards securing a stable key raw material supply chain in the region," said LG Energy Solution CEO Youngsoo Kwon.

"By constantly investing in upstream suppliers and establishing strategic partnerships with major suppliers of critical minerals, LGES will continue to ensure the steady delivery of our top-quality products, thereby further advancing the global transition to EVs and ultimately to a sustainable future," he added.

Piggybacking off this agreement, the companies announced that Electra would supply LG Energy Solution with 3,000 metric tons of cobalt contained in a cobalt sulfate product in 2025 and an additional 4,000 metric tons in each of the following years through 2029 for a total of 19,000 metric tons, nearly triple the 7,000 metric tons from the initial deal.

"LG Energy Solution continues to strengthen its position as a global leader in the electric vehicle supply chain through its investments in Ontario and active collaboration with Canadian companies developing critical minerals and battery materials," said Electra Battery Materials CEO Trent Mell.

As a top electric vehicle battery manufacturer, which supplies Tesla and other automakers, LG Energy Solution has been positioning itself to better provide the critical component to EVs, and by investing in the first and currently only cobalt refinery in the West, it has sounded out one of the first breakaways of imported critical minerals for North America, and hopefully, signals that many more are yet to come. DMN


The Aurora Borealis lights up the sky above Glencore's Raglan nickel mine in northern Quebec.
GLENCORE

# Nickel's evolving role in clean energy

## Advancing extraction, processing, and recycling technologies

By K. WARNER
FOR DATA MINE NORTH

**WHILE LITHIUM HAS BEEN** the poster child for optimism and controversy in equal measure, nickel has its own crucial role to play in the batteries powering the clean energy future – increasing range and capacity – but is traditionally carbon-heavy to produce.

For nickel, the industry's focus has been twofold – obtaining enough and moving the needle between untenable quantities of emissions from mining and processing and the battery and alloying metal's necessary inclusion in nearly all energy transition technologies.

The current challenge is to nearly double the mineral supply in tandem with the booming electric vehicle and renewable energy industries while meeting environmental, social, and corporate governance (ESG) requirements.

The resulting reevaluation of mining and recycling infrastructure is producing new policies and private sector incentives focusing on where commodities are being sourced and how they are being processed. A subsequent wealth of financial and political support has gone into new mines, mining tech, global surveying, multi-industry engineering, and research and development – all hinging on expectations of drastically improved sustainability.

The United States still relies on imports for about half of its annual nickel consumption, according to the U.S. Geological Survey. Currently, the more desirable import sources of nickel include Canada, which accounts for about half of America's imported supply, rounded off by Australia, Norway, and Finland. Russia has traditionally been a major supplier of nickel, a source the U.S. is hoping to move away from.

Companies like Tesla have had eyes on nickel from a mutually beneficial EV sales partnership with Indonesia – the world's biggest

producer with twice the reserves of Australia and Canada combined. This Australasia island nation, however, has struggled to stay out of the news for its extremely poor worker safety and environmental record.

## Bringing nickel home

The USGS added nickel to the 2022 critical minerals list due to its importance to the U.S. economy and clean energy goals, coupled with a high risk of resource disruption. EV manufacturers in the U.S. have been eager to earn incentives through the switch over to domestic nickel and increased recycling.

Presidential determinations continue to be signed into law, strengthening the U.S. industrial base for clean energy industries, encouraging domestic mines, and increasing byproduct and coproduct development at existing mines and other industrial facilities.

Nickel is one of the most technically challenging metals to process and refine, with every operation uniquely dependent on the type of ore deposit, which defines everything that follows in the value chain.

There is only one operating nickel mine in the U.S. – the Eagle Mine in Michigan, operated by a subsidiary of Toronto-based Lundin Mining, which produces raw nickel concentrate. The concentrate is then sent to Canadian smelters and returned to the U.S. primarily as stainless-steel products.

Michigan and the Midwest have the most nickel resource concentrations across the U.S., where several mining prospects have been working through red tape and local resistance to break ground.

Exemplifying this struggle are the NewRange and Twin Metals ore deposits in Minnesota, which recently had their permits revoked due to concerns over nearby bodies of water.

Nickel is often bound up in sulfide ores that can generate sulfuric acid when exposed to the environment. Sulfide ore and tailings exposed to air and moisture can create a chemical reaction of sulfuric acid, a historically devastating environmental contaminant.

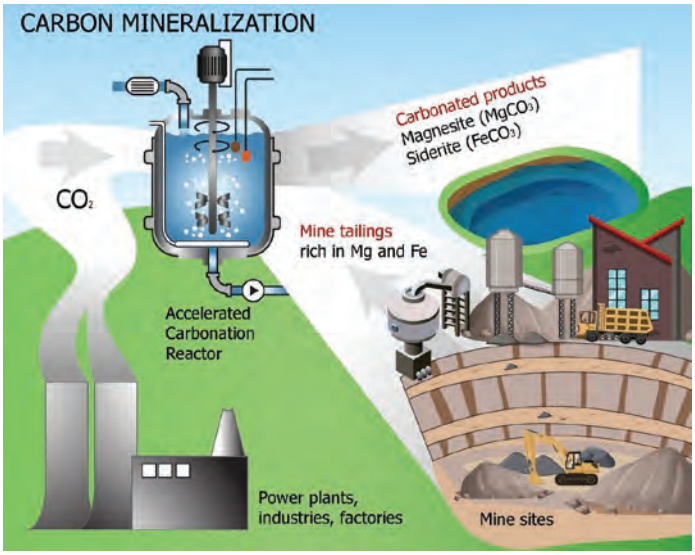
## First case study: Tesla

Looking to prove that nickel can be responsibly mined in the U.S., Talon Metals and joint venture partner Rio Tinto, the world's second-largest metals and mining corporation, contracted with Tesla to supply 75,000 metric tons of nickel concentrate and smaller quantities of cobalt produced from the Tamarack nickel project in Minnesota.

Hopes are high that the mine's cutting-edge design will speed through permitting so that it can begin production in 2027.

"The Talon team has taken an innovative approach to the discovery, development and production of battery materials, including to permanently store carbon as part of mine operations and the investigation of the novel extraction of battery materials," said Drew Baglino, senior vice president of powertrain and energy engineering at Tesla. "Responsible sourcing of battery materials has long been a focus for Tesla, and this project has the promise to accelerate the production of sustainable energy products in North America."

The aboveground footprint of the mine would be small, 80 acres at most, with no ore processed on site. Material would be transported by rail to a processing facility in North Dakota, where all the tailings would be sealed in concrete for storage. All water from mine operations would be collected and treated before being returned to the environment. Access from the surface to the ore body below the surface would be through sealed, concrete-lined tunnels to limit seepage.



MICHIGAN TECHNOLOGY UNIVERSITY

Michigan Tech is working on a project to permanently mineralize and store carbon dioxide as part of the mining process.

BHP

Low-carbon nickel sulfate produced at BHP's Nickel West operation.

"We do not believe that addressing climate change should come at the expense of the natural environment," said Talon Metals CEO Henri van Rooyen. "We can move to a clean energy system, protect the environment, respect tribal culture resources and self-determination, involve front line communities and working people in project approvals and create good paying union jobs. It doesn't have to be a choice."

## Second case study: Lifezone Metals

Lifezone Metals plans to pair one of the largest undeveloped high-grade nickel sulfide deposits in the world with proprietary green-processing technology to produce cleaner metals.

Currently, smelting is responsible for 7% of all global CO2 emissions, according to estimates from the U.S. Department of Energy's Advanced Research and Projects Agency-Energy.

Enter the cheaper, cleaner processes of hydrometallurgy – the use of water-based solutions to extract metals. This technique is on the rise, competing with smelting as the chief method of producing nickel.

With this technology, Lifezone has developed a proprietary process to replace carbon-intensive smelting as well as avoid

harmful sulfur dioxide emissions entirely, reducing these greenhouse gases from mining operations and industry supply chains.

The technology will be piloted at Lifezone's Kabanga project in Tanzania, one of the largest and highest-quality undeveloped nickel deposits in the world. Through future licensing, the proprietary technology can eventually be made available in the U.S., Canada, and other countries.

Kabanga and its hydromet processing facility have the potential to be one of the lowest cost, greenest lithium, copper, and cobalt production facilities in the world, with the aim to maximize the use of hydroelectric and renewable energy to power its mine and refinery sites as well.

"We see the metals supply chain as the major bottleneck holding back the promise of wider EV adoption in the U.S.," said Lifezone CEO Chris Showalter. "We believe that this lower cost, cleaner and more effective solution can also help to facilitate re-shoring battery manufacturing back to the U.S., and ultimately the electrification of society as a whole."

## Breakthroughs on the horizon

Michigan Technological University has received $2.5 million from the U.S. Department of Energy to test an innovative method that dramatically speeds up carbon dioxide sequestration and also aids in the extraction of critical minerals from mine tailings.

The project will be piloted by Eagle Mine in partnership with Polymet Mining in Minnesota, two major mining companies with nickel operations. Eagle Mine anticipates producing 440 million pounds of nickel and 429 million pounds of copper before exhausting its ore body.

Michigan Tech's project – "Energy Reduction and Improved Critical Mineral Recovery from Low-Grade Disseminated Sulfide Deposits and Mine Tailings" – seeks to permanently and cleanly mineralize and store carbon dioxide during mineral extraction. The method greatly accelerates the kinetics of carbon dioxide sequestration to achieve the result on an industrial scale in just four hours.

Michigan Tech's project is the only one in the state to receive funding from Mining Innovations for Negative Emissions Resource Recovery (MINER), a new initiative through the DOE Advanced Research Projects Agency-Energy fund.

TALON METALS CORP.

Kids check out Talon Metals' "powered by nickel" Tesla EV.

>> *"We do not believe that addressing climate change should come at the expense of the natural environment."*

*–Talon Metals CEO Henri van Rooyen*

The MINER initiative funds research that increases domestic mineral yields and decreases required energy and emissions in order to improve critical minerals extraction with market-ready technologies.

## Traditional and urban reclamation

DOE continues to promote an expanded recycling industry to complement increased production. Considerable intellectual and material investments are still needed to develop a more specialized industry capable of recovering various critical minerals before a circular economy is possible.

Urban mining focuses on the potential for cities to be considered mineral resources in the same way geological reserves serve as a source of raw materials. As a way to supplement primary mining, what were once considered waste materials have to transform into untapped urban mineral reserves ready to be recovered and put back into use.

Beyond landfills and tailings, the urban mining approach takes an opportunistic, holistic view of raw materials and how to best recover them, starting with forward-thinking product engineering, building in a second life and easier recovery.

With policymakers and industry leaders encouraged to see the whole picture, truly closed-loop supply chains can be developed to unlock resources closer to where they are needed, increase resource independence and reduce costs and energy use.

Developing a robust recycling infrastructure is likely going to be the final step toward achieving net-zero emissions as a society. DMN


Lithium-rich Salinas Grandes salt flats in Argentina, one of three countries that make up Latin America's Lithium Triangle.

ADOBE STOCK

# The 'white gold' rush for lithium

## Developing greener strategies to avoid a battery metal deficit

By K. WARNER

FOR DATA MINE NORTH

**LITHIUM IS AN INDISPENSABLE** element in the clean energy transition for several key reasons; like all alkaline metals on the periodic table, it has one more electron than it strictly needs, and this tendency to shed electrons makes it well-suited for passing them back and forth between cathode and anode, charging and discharging thousands of times without degradation.

Pure lithium does not occur in nature, but traces are found throughout nearly all igneous rocks, mineral springs, certain clays, and the world's oceans. It is the lightest metal and sports a high electrochemical potential, making it the first contender in all energy storage solutions.

In a word—it's perfect for use in energy-dense and long-lived rechargeable batteries. And with fossil fuels on their way out, the world will need somewhere to store the next wave of renewable energy.

### Powering the future

Lithium compounds cover a broad spectrum of uses; in pharmaceutical and biochemistry applications, in polymers, ceramics and glass, metallurgy and coatings and as a high-temperature lubricant. It is alloyed with aluminum for lightness and improved strength in armor plating, aircraft, bicycle frames and high-speed trains.

It can also be used as a means of storing hydrogen for use as a fuel and as a non-chlorofluorocarbon coolant alternative in large-scale commercial applications such as air conditioning for office buildings, hospitals, and industrial process cooling.

Lithium has since become necessary for strategic, industrial, and commercial applications.

Lithium-based batteries not only allow smartphones and laptops to become lighter and longer-lasting but are found inside everything from pacemakers to power tools.

It is, however, electric vehicles and renewable energy storage that are powering enormous new demand for this lightest of metals.

## A rich resource

According to the U.S. Geological Survey lithium report for 2023, cumulative global sources of lithium have been estimated at 98 million metric tons, a number climbing each year as further deposits are avidly sought out and secured.

Identified lithium resources within the U.S. are 12 million tons, with continuing development and exploration activities of various naturally occurring brines, mineral deposits and clays (clay extraction is more expensive, though Tesla has a new method patented).

There is presently only one working U.S. domestic lithium mine in Nevada, with dozens more at various stages of exploration and development. Other promising locations include Southern California, North Carolina, South Dakota, Arizona, Arkansas, Utah, and the most recent discovery of a substantial hard-rock cache in Maine, still in the permitting process.

Brine-based lithium production is also being expanded upon in South America, which has the highest occurring concentration of the resource at 52 million tons. Hardrock mining production from Australia is leading the industry with 9.9 million tons and more on the rise, being the cheapest and most efficient to extract. Canada follows with a potential for 2.9 million tons of hard rock resources and further mineral and brine projects being explored as well.

In short, there is technically enough lithium to put the entire population of the planet into an EV.

Unfortunately, only about a third of that resource (32 million tons) qualifies as "reserves," which are resources that are considered economically viable to mine according to accessibility, extraction costs, and a new but important criterium – overall environmental, social and governance rating.

"There is not sufficient supply to meet this demand projection based on our knowledge of known projects today. That includes all projects whether they are under construction, in feasibility or still in exploration," said Glyn Lawcock, Global Head of Mining Research at UBS investment bank.

GENERAL MOTORS

This lineup of GM electric vehicles is the various sizes and ranges of EVs and the lithium battery packs that go into them.

The defining issue, then, isn't whether there is enough but how fast the world's lithium-hungry industries can get it while emphasizing resource stewardship moving forward.

## Racing the clock

The lithium mining sector is racing toward 2030, an important deadline for several countries bent on reducing carbon emissions by at least half through electrification of the transportation industry.

In the U.S., the federal stance on internal combustion cars is shared by several countries, including the UK, Canada, Sweden, the Netherlands, France, and Norway – all of which have announced a phaseout by 2035, with only Chinese and Japanese governments still allowing for hybrids.

CONTROLLED THERMAL RESOURCES LTD.

Mud pots from the lithium enriched geothermal waters at the Hell's Kitchen project in Southern California.

This short timeline is pushing the critical minerals markets toward very tight supply margins, with strong potential for moving into a deficit in spite of available reserves during the latter half of this decade.

Investment in new and increased production, workforce training, technological solutions, and an expanded recycling market will all be key to supporting a sustainable economy in North America and beyond.

## Clarifying the numbers

Due to unpredictable sociopolitical influences and as laws pass or fail, there are few forecasts attempted past 2040. Several factors complicate projections of global lithium demand in the interim and indicate that supply workarounds are needed, even with mining and prospecting going full bore:

• Widely differing and improving proprietary designs: there is no typical amount of lithium in an EV battery, depending on chemistry and size. A Tesla Model S battery, for example, contains around 62 kilograms (138 pounds) of lithium, while the next iteration of Hyundai Ioniq may be more representative of a future average at roughly 10 kg (22 lb).

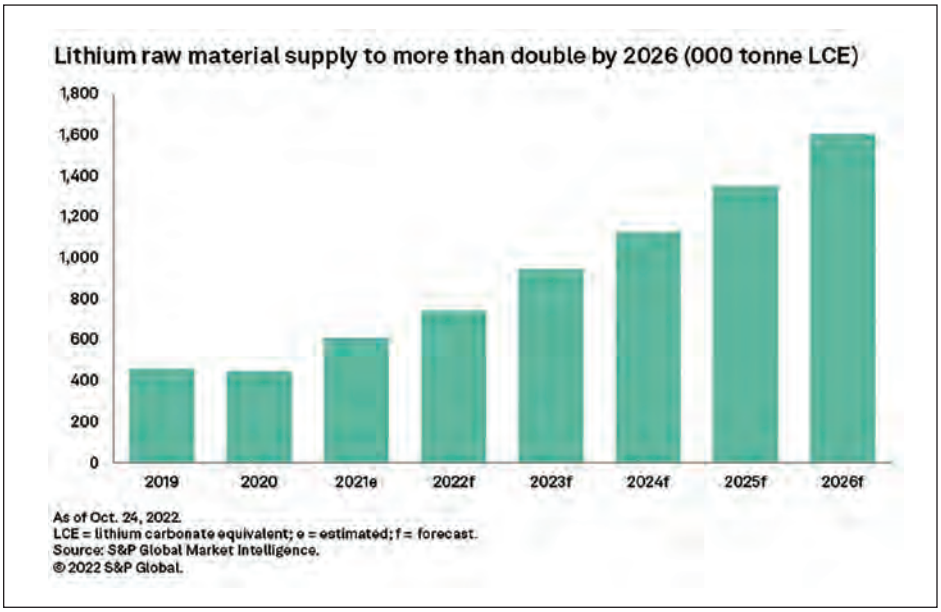
• With the original industry projections of EV purchases only comprising a third of new car sales by 2040, adding government bans on gas-powered vehicle sales would have EVs leap to 25% of new car sales in 2030 and over 60% by 2035.

• American businesses, vehicles, battery components, and materials need to be largely home-grown to take advantage of the Biden administration's incentives, grants and loans in the U.S. clean energy and transportation industries.

• U.S. mining engineering programs and, by extension, qualified workforce numbers have gone down for years since the dissolution of the former U.S. Bureau of Mines, which removed all funding for mining schools under the Mining and Mineral Resource Institutes Act of 1984.

"We're going to need a significant increase in battery production to supercharge America's clean energy future, which means we urgently need to build up our capacity to research, develop, manufacture, and market batteries right here at home," said U.S. Secretary of Energy Jennifer Granholm.

"Strengthening our domestic supply chain will accelerate our efforts to decarbonize the economy –helping to power electric vehicles and boost grid storage and resiliency," she added. "We must seize the opportunity for the U.S. to lead an emerging global industry to create good-paying jobs for American workers that will be in demand for decades to come."




S&P Global forecasts that lithium demand will more than double by 2026.

## How much do we need?

With the updated projections for EV and stationary storage battery demand increasing by as much as ten-fold by 2030, the world will need at least 2.1 million metric tons of lithium annually, nearly ten times what is currently being produced, according to projections by the International Energy Agency.

Expansion has thus far been facilitated by new and existing mining operations scaling to match demand, shrewd early investments from countries like China, and constantly improving extraction processes, which are themselves utilizing greener industrial technologies such as battery-electric vehicle fleets and equipment.

The brunt of net-zero objectives rests heavily on first decarbonizing the transportation industry in three of the largest EV markets – the European Union, the U.S., and China.

To meet those demands, the IEA proposed that construction of an additional 50 to 65 gigafactories averaging 35 GWh of annual production capacity would be needed by 2030.

## Playing the long game

While the U.S. originated the lithium industry and led the world until the mid-1990s, there is now only one operational lithium mine in Nevada, with production at a modest 5,000 tons a year, which means that the U.S. will struggle in this decade to break its dependence on raw and processed mineral imports.

Similarly, Canada's limited production of lithium tapered off in 2021. Several companies have since been working to revitalize the industry, developing about two dozen new lithium projects from traditional hardrock mining as well as less conventional oilfield brines and industrial wastewaters across Ontario, Quebec, Alberta, Manitoba, and Saskatchewan.

Incentivized by policies like DOE's Lithium-Ion Battery Recycling Prize, more automakers and dealerships have begun to partner with EV and hybrid battery recycling and refurbishing businesses to offload retired batteries into second-life, disassembly, or end-of-life materials recycling.

Over the last five years, a growing number of traditional automotive companies such as Volkswagen, BMW, General Motors, and Ford have taken a page from Tesla's book and also begun to directly invest in mining operations and even develop their own battery production and recycling facilities to better establish and control an efficient and circular supply chain and pricing.

A clause in the industry-sweeping U.S. Inflation Reduction Act has designated EV battery materials recycled in the U.S. as American-made, regardless of their origin,

ADOBE STOCK

Batteries for the clean energy transition have driven a 300% increase in the demand for lithium over the past five years and are expected to power another nearly tenfold increase by 2030.

encouraging automakers worldwide to take advantage in order to qualify for EV production incentives as a boost to North America's developing recycling industry.

"If you give me a lithium-ion battery pack, I probably will give you money back for it. And that's the beauty of it. The intrinsic value of that battery pack is higher than the cost of recycling," said Dirk Spiers, founder and CEO of Spiers New Technologies, which services a growing list of companies, including GM, Ford, Stellantis, Porsche, Volkswagen, Nissan, Toyota and Volvo.

Mining companies are also beginning to explore integrated conversion facilities, developing processing capacity in tandem with extraction. Meanwhile, more auto manufacturers are constructing vehicle, battery, and recycling capacity into connected complexes.

## Introducing urban mining

Like all conventional mining, lithium takes its own environmental toll with carbon emissions, water, and land degradation, necessitating a push for options with a lower environmental footprint.

If further regulatory support and a robust infrastructure can be developed, a new era of recycling –coined "urban mining" – has the goal of being cost-effective enough to make up the supply shortfall where higher-cost deposits would otherwise need to be developed to meet demand.

Most consumer electronics, laptops, phones and EVs are not yet being produced with recycled minerals, and only about 20 to 30% of e-waste is being recycled at all.

BMW, Mercedes, Jaguar, and Honda are in the handful of name-brand exceptions utilizing actual closed-loop components in vehicles today.

"All cars are essentially crushed and shredded and then all that steel is recycled and goes right back into new cars," said Mike O'Kronley, CEO of Ascend Elements, a U.S. battery recycler. "That industry is already there. And so what needs to develop is the recycling for the metals in the lithium-ion batteries [to] put them back into the supply chain. That's what we're doing."

Outdated, toxic, and carbon-heavy methods of smelting and leaching have been vastly improved upon; from battery shredding to automated disassembly, upcycling as stationary storage, refurbishment, or complete breakdown into mineral components ready to rejoin the supply chain.

"With all these batteries in circulation, it just seems super obvious that eventually we're going to build a remanufacturing ecosystem," said J.B. Straubel, former chief technical officer of Tesla, who intends to use e-waste from landfills as well.

Redwood Materials is Straubel's brainchild and one of the first wave of emerging companies and well-funded startups solving the challenge of recovering critical minerals from the waste stream and putting them back into manufacturing.

Other North American companies on the fast track to achieving 90% efficiency or better are Li-Cycle, American Battery Technology Company, and Retriev.

There are also a growing number of unconventional lithium resources derived from industrial waste, such as boron and bauxite mining tailings, water waste from oil and gas fields, incorporating filtration into geothermal power plant processes, and modifying existing ocean desalination projects.

## Greenlighting a revolution

The cumulative demand for critical minerals at home, in our transportation and broadening swathes of industry is less of a growth curve than an exponential paradigm shift spurred by much-needed international climate change actions, serious adoption of the Paris Agreement international treaty and Tesla's game-changing Model 3, the first mass-produced long-range battery EV.

The forward momentum of these policies and technologies is exactly what is needed to put North America and the world on the right track toward a sustainable net-zero economy built on industries to be proud of and excited for. DMN


A colorful Alaska west coast sunset paints the backdrop for the expanded Graphite Creek exploration camp in western Alaska.
GRAPHITE ONE INC.

# Graphite demand outpaces EV sales

## By 2035, graphite demand could by 8X 2022 mine production

By SHANE LASLEY
DATA MINE NORTH

**EVERY ELECTRIC VEHICLE** rolling off an assembly line increases the demand for graphite by an average of around 160 pounds. With more than 30 million EVs expected to hit global highways each year by 2030 and upwards of 45 million by 2045, the transition to e-mobility will require up to eight times more graphite than was mined globally during 2022.

While graphite has not received the attention of other EV battery ingredients such as cobalt, lithium, and nickel, this highly useful cousin to diamonds and coal is the single largest ingredient in lithium batteries. The reason for this is that while all the current EV battery technologies rely on some mixture of elements in the cathode (negative electrode), graphite does more than 90% of the heavy lifting on the anode (positive electrode) side.

"Increases in graphite demand will be predominantly driven by its use as the anode active material in batteries for EVs and stationary energy storage systems," the U.S. Department of Energy penned in its 2023 Critical Materials Assessment.

The demand for graphite is expected to outpace the number of new electric cars, trucks, vans, and SUVs hitting global highways as the nascent EV sector matures, according to Adamas Intelligence's biannual "State of Charge" report published in March.

The higher quantities of graphite per EV is due to automakers introducing fully electric versions of a wider range of vehicles, including SUVs, vans, and trucks, as well as vehicles with enough range to traverse North American highways, all of which require larger batteries and more graphite.

For example, the Tesla Model 3, which was the vanguard of the EV transition, has about 100 pounds of graphite in its batteries, whereas full-size SUVs like the GMC Hummer require roughly 500 lb of this anode ingredient.

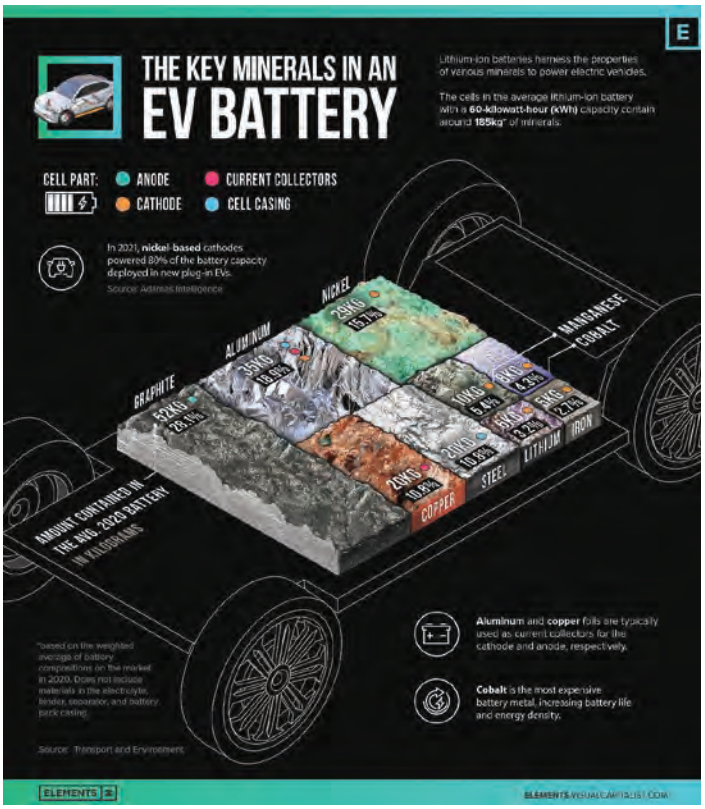
Adamas Intelligence Managing Director Ryan Castilloux told Data Mine North that this trend toward bigger EV batteries with more graphite is anticipated to continue to rise disproportionally faster than total EV unit sales.

### Up to 8X demand growth

Global analysts estimate that by 2030, it will take 5 to 6 million

NOUVEAU MONDE GRAPHITE INC.


VISUAL CAPITALIST




**Above: Nouveau Monde Graphite CEO Eric Desaulniers and COO Bernard Perron with a Cat battery-electric 793 mining truck at Caterpillar's Tucson Proving Ground in Arizona. Right: A Visual Capitalist infographic showing the minerals and metals in an electric vehicle battery. Below: Syrah Resources' Balama Mine in Mozambique is a globally significant source of the graphite needed for lithium-ion battery anodes.**

SYRAH RESOURCES LTD.

metric tons of graphite per year to fill lithium battery demands. This is roughly four times the 1.3 million metric tons mined globally, according to the U.S. Geological Survey's Mineral Commodities Summaries 2023.

In its highest demand projection, DOE forecasts that global graphite demand could be more than eight times current production by 2035.

"In 2035, flake graphite demand for energy applications will account for 91% of the total demand, and EV batteries will account for 74% of the total demand," the U.S. Energy Department inked in its Critical Materials Assessment.

Silicon and other materials could be used as lithium battery anodes, "but complete substitution is unlikely due to technological challenges and performance concerns," according to the DOE.

With no domestic graphite mines and only small startup graphite refining facilities, the U.S. remains largely dependent on imports from China, which currently produces more than 60% of the world's mined graphite and nearly 90% of advanced anode material.

This is why DOE ranks graphite near the top of its list of minerals critical to America's energy future.

During an opening address at the Battery Gigafactories USA 2023 conference in Washington, DC, Benchmark Mineral Intelligence CEO Simon Moores stressed the importance of developing domestic mining and refining of graphite.

"When you have a lock on the flake graphite you have a lock on the anode material," he explained.

North America can lock down a reliable, domestic supply of graphite with the large deposits of this battery material in the U.S. and Canada.

## Largest US graphite source

A good portion of North America's flake graphite needs could be locked down at Graphite One Inc.'s Graphite Creek project on Alaska's west coast.

"The Graphite Creek graphite deposit, located in the Kigluaik Mountains 60 km north of Nome on the Seward Peninsula, Alaska, is the largest known flake graphite resource in the USA and is among the largest in the world," USGS penned in a report on the geology of this world-class deposit.

According to a calculation completed in early 2023, Graphite Creek hosts 37.6 million metric tons of measured and indicated resources averaging 5.15% (1.9 million metric tons) graphite; plus 243.7 million metric tons of inferred resource averaging 5.14% (12.3 million metric tons) graphite.

A 2022 prefeasibility study for Graphite One envisioned a vertically integrated graphite supply chain that includes a mine at Graphite Creek that would produce an average of 51,813 metric tons of graphite concentrate per year and a processing and recycling facility in Washington that would upgrade the concentrates into 49,600 metric tons of spherical coated graphite that serves as the anode material in lithium-ion batteries and 25,400 metric tons of other advanced graphite products per year.

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Core from drilling a high-grade lens at Graphite Creek, a world-class deposit in Alaska.

GRAPHITE ONE INC.

The more than 14 million metric tons of graphite outlined in all resource categories is enough to support a mine of the size considered in the prefeasibility study for more than 200 years. As colossal as this deposit is, the resources outlined so far only account for about one-third of the roughly 10-mile-long graphite trend running across the property.

"The Graphite One project is in a league of its own, in terms of the scope of the resource in the ground in Alaska and the vision the company has for manufacturing anode materials and recycling batteries in Washington state," Sen. Lisa Murkowski, R-Alaska, said during a keynote address during an Arctic critical minerals summit held in Washington, DC.

Given that there are currently zero graphite mines in the U.S., North American automakers and the U.S. government want to see a Graphite One supply chain that better matches Graphite Creek's world-class potential with rocketing demand being driven by the transition to EVs powered by clean energy.

## Pentagon invests in Graphite One

With the U.S. military leaning more heavily on lithium battery technologies, coupled with securing energy transition materials being a top White House priority, the U.S. Department of Defense announced in July that it is investing $37.5 million in the accelerated completion of a feasibility study for a larger Graphite One supply chain.

"This Department of Defense grant underscores our confidence in our strategy to build a 100% U.S.-based advanced graphite supply chain – from mining to refining to recycling," said Graphite One CEO Anthony Huston. "The U.S. simply cannot maintain a 21st century tech-driven economy without critical minerals like graphite."

WADE PAYNE FOR GENERAL MOTORS

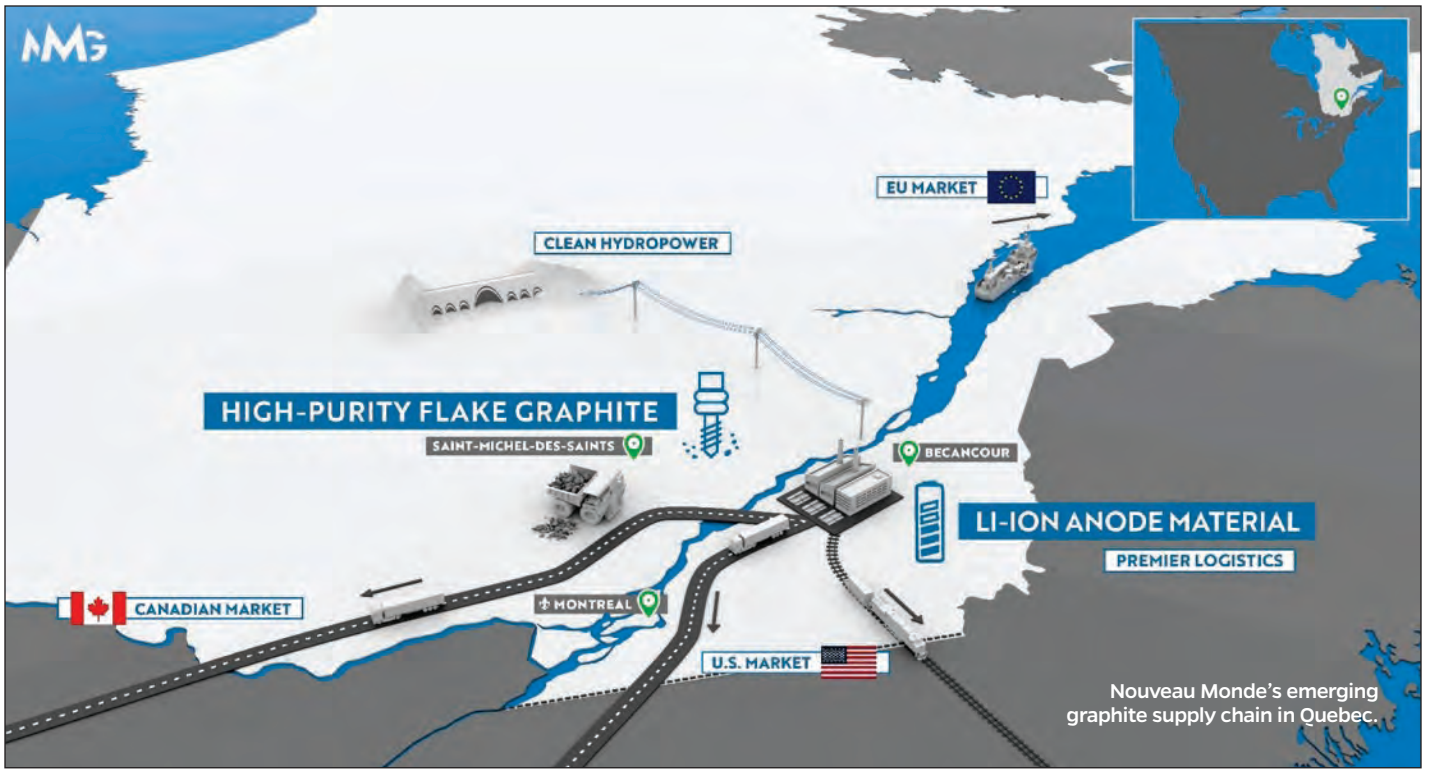
**An average of around 160 pounds of graphite goes into the electric vehicles rolling off of global assembly lines. Larger and longer-range EVs, like the Cadillac Lyriq above, require more graphite for their batteries.**

The DOD backing for the all-American Graphite One supply chain follows a 2022 White House memorandum directing the Pentagon to utilize Defense Production Act Title III funding to support sustainable and responsible domestic production of strategic and critical minerals.

"The agreement with Graphite One (Alaska) advances the Defense Department's strategy for minerals and materials related to large-capacity batteries," Department of Defense Assistant Secretary for Industrial Base Policy Laura Taylor-Kale said in a mid-July statement on the $37.5 million DPA Title III award.

The DPA Title III funding awarded to Graphite One is half of the estimated $75 million needed to complete a feasibility study for this larger Graphite One supply chain.

NOUVEAU MONDE GRAPHITE INC.



Nouveau Monde's emerging graphite supply chain in Quebec.

## ESG-forward graphite supply chain

In Canada, Nouveau Monde Graphite Inc. is also scaling up a globally significant graphite anode supply chain to help meet the demands in North America and Europe.

"NMG is positioning itself as North America's largest, fully integrated natural graphite production to relieve battery and EV manufacturers from their overreliance on Chinese production," said Nouveau Monde Graphite President and CEO Eric Desaulniers.

This mine-to-anode material supply chain in Quebec begins at Nouveau Monde's Matawinie mine project about 100 miles (160 kilometers) north of Montreal.

A feasibility study updated in July details plans for a mine at its Matawinie project that is expected to produce an average of 103,328 metric tons of high-purity flake graphite concentrate per year.

These concentrates will be trucked roughly 95 miles (150 kilometers) to the company's advanced material plant at Becancour, a region along the St. Lawrence River that has become known as "Lithium Valley" due to the numerous battery processing facilities being built there. Here the concentrates will be refined and upgraded to 42,616 metric tons of coated spherical anode material for lithium batteries and 3,007 metric tons of large flake graphite for other industrial purposes.

As a company focused on applying the highest ESG standards to producing an ingredient vital to the transition to green transportation and energy, Nouveau Monde has taken enormous strides in shrinking the carbon footprint of its Quebec operations.

"At every stage of development, management has worked to expand the field of possibilities for sustainability in our sector," said Nouveau Monde Graphite Chair Arne Frandsen.

This idyllic vision includes electric mining equipment charged with Quebec's abundant clean hydropower to do the digging and hauling at Matawinie. This idea is so ahead of the curve that the electric mining equipment it plans to use has not been invented yet.

Nouveau Monde and globally recognized mining equipment manufacturer Caterpillar Inc. forged a preliminary win-win electric mining equipment partnership in 2021.

This year, the two companies formalized this alliance with a definitive agreement for Caterpillar to supply Nouveau Monde with electric mining equipment. In turn, the junior mining company will supply the global heavy machinery manufacturer with graphite for the batteries of electrified versions of the famed Cat "yellow iron."

"This project is an exciting one as it highlights what is possible when an effective energy transition roadmap is implemented that bridges the traditional product line to an integrated, electrified site of the future," said Caterpillar President Denise Johnson.

## Larger Quebec graphite potential

As Nouveau Monde builds an electrified graphite mine of the future at Matawinie, it is advancing toward the development of a much larger graphite operation at the world-class Lac Guéret deposit on Mason Graphite Inc.'s Uatnan project in Northern Quebec.

A road-accessible project about 175 miles (280 kilometers) north of the St. Lawrence River, Lac Guéret hosts 65.6 million metric tons of measured and indicated resources averaging 17.2% (11.2 million metric tons) graphite.

In mid-2022, Nouveau Monde entered into an option agreement to earn a 51% joint venture interest in this large and high-grade graphite deposit.

Early this year, Nouveau Monde and Mason unveiled a preliminary economic assessment that considers a mining operation at Uatnan that would produce roughly 500,000 metric tons of graphite concentrate annually for 24 years, making it one of the largest graphite projects being considered for development globally.

The world-class size of this operation is in step with the enormous graphite demand on the horizon.

"The Uatnan Mining Project aligns with our vision of progressive, integrated growth that caters to the market's requirements for high-quality graphite materials, local supplies, ESG-driven development, and large volumes to meet EV production levels," said Frandsen.

### U.S. Gulf Coast graphite

Another North American graphite anode material supply chain is emerging in the Southeast U.S. Gulf Coast states of Louisiana and Alabama.

In Louisiana, Syrah Resources Ltd. has received major federal backing to scale up the production of battery-grade anode materials at its Vidalia plant.

In 2022, the DOE Loan Programs Office loaned Syrah $107 million to fund the expansion of Vidalia, which is currently at a scale to produce sample graphite anode material for automakers like Tesla Inc. and Ford Motor Company, both of which have offtake agreements for future supply.

"Projects like Syrah Vidalia are critical to our national security, our foreign policy, building our supply chain, and our economy," said DOE Loan Programs Office Director Jigar Shah.

Australia-based Syrah is expanding this graphite anode materials plant to 11,250 metric tons of annual capacity and plans to further expand the facility to 45,000 metric tons per year.

In addition to the loan, Syrah received a $219.8 million federal grant as part of $2.8 billion in awards by DOE for 20 projects to expand the domestic manufacturing of lithium battery materials.

This grant, along with roughly $225 million invested by Syrah, will go toward the expansion of the Vidalia graphite facility.

Feedstock for Vidalia will come from Syrah's Balama mine in Mozambique, which hosts 16.9 million metric tons of graphite in 110 million metric tons of reserves averaging 16% graphite. This is enough for the mine to supply 350,000 metric tons of raw graphite annually for more than 50 years.

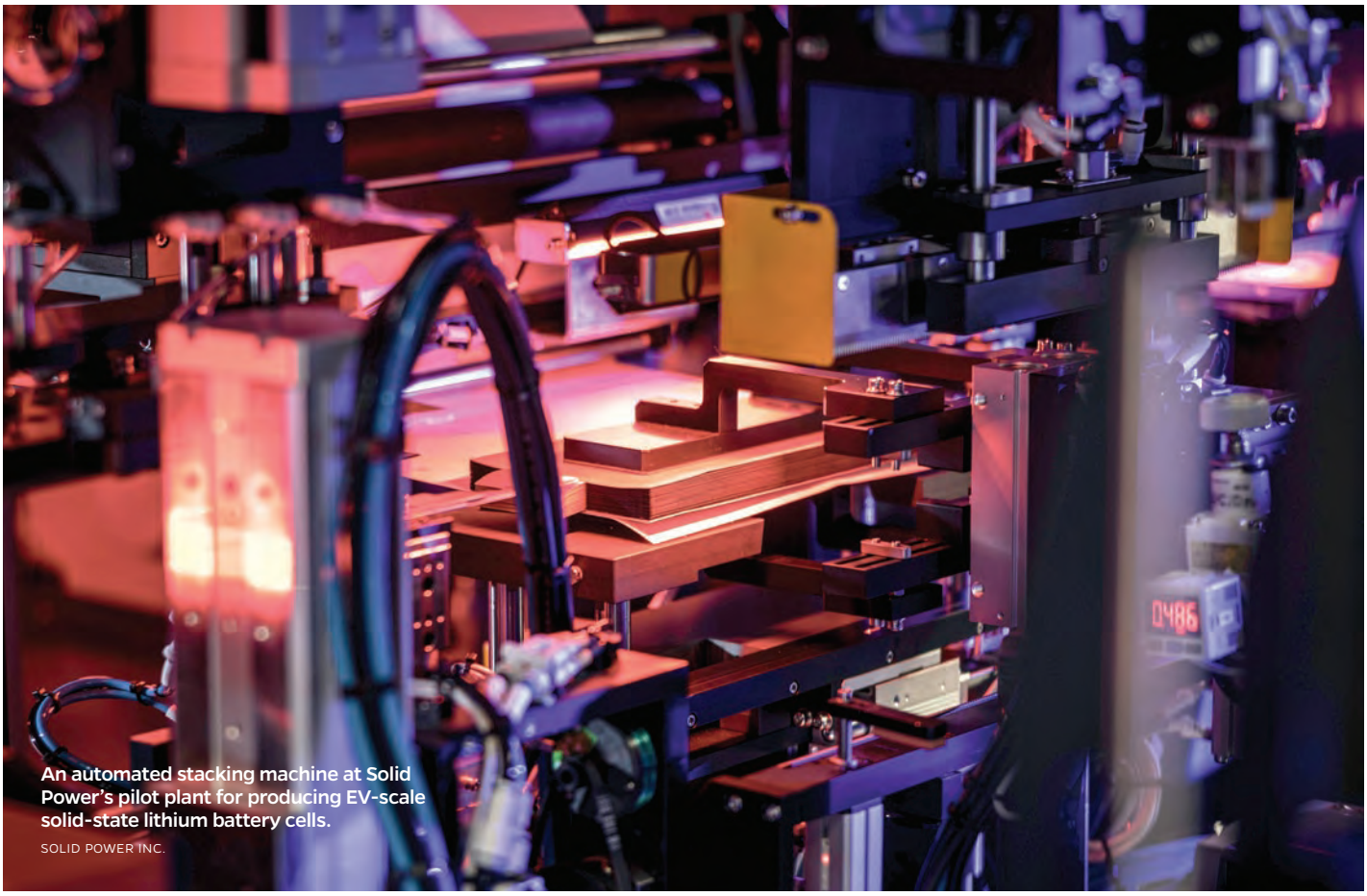
In Alabama, Westwater Resources Inc. is putting the finishing touches on a phase-one processing plant that will use a proprietary process to upgrade raw graphite into 7,500 metric tons of battery-grade anode material per year.

At the onset, Westwater's Alabama Graphite Products subsidiary will import graphite as a feedstock for the refinery near the town of Kellyton, Ala. Westwater, however, intends to develop a mine at its Coosa project in the famed Alabama Graphite Belt.

According to a 2015 estimate, Coosa hosts 26 million short tons of indicated resource averaging 2.89% (754,000 tons) graphite and 97 million tons of inferred resource averaging 3.08% (3 million tons) graphite.

Westwater Resources Executive Chairman Terence Cryan said the company plans to leverage the Coosa deposit to establish an all-Alabama vertically integrated graphite supply chain capable of producing more than 40,000 metric tons of advanced anode material per year once the mine is in production and the second phase of the Kellyton processing plant is complete, both currently slated for 2028.

Combined with the Alaska-Washington and Quebec graphite supply chains, the emerging Gulf Coast states graphite hub is helping ensure North America has a lock on the anode material needed to charge the EV revolution. DMN



An automated stacking machine at Solid Power's pilot plant for producing EV-scale solid-state lithium battery cells.

SOLID POWER INC.

# Solving solid-state batteries

## Defeating dendrites, reducing cost, and streamlining production

By K. WARNER

FOR DATA MINE NORTH

**WHILE MOST LEADERS** in the clean energy sector strongly indicate the concept of solid-state batteries is better, a few hurdles have long held this superior rechargeable battery in the realm of pacemakers and smart watches and out of electric vehicles where they are desperately needed.

Solid-state technology replaces the liquid electrolyte in lithium batteries with a solid ceramic or polymer material. This increases energy density, stability, and heat resistance. For EV drivers, this means longer range, faster charging, and essentially zero chance the battery will catch fire.

Since solid-state batteries can achieve a larger capacity and higher output in a smaller form than lithium-ion batteries, they are also making their way into aerospace and naval engineering, which have massive fuel demands that haven't been overlooked in overall clean energy plans for the transportation industry.

A transition to solid-state would also likely increase battery costs and threatens to put companies back at square one, reinventing the EV battery manufacturing processes in order to scale them back up.

### Superior design in its infancy

The chemistries of solid-state batteries are generally the same as liquid electrolyte cells – a positive electrode made with similar compounds to lithium-ion batteries but with a solid electrolyte and an anode made of pure lithium to handle much higher energy loads.

While liquid electrolytes have structural restrictions to prevent leakage, solid-state batteries possess a high degree of freedom in shape, adding more power in a lightweight, configurable package.

Safety is also a buzzword in engineering solid-state batteries, which by nature have excellent thermal stability, even if punctured. Due to this reduced flammability, these batteries don't require the same cooling systems to prevent overheating, subtracting further weight from an already compact system.

This removes the key fire risk associated with liquid electrolytes from short-circuiting or physical damage to the membranes separating electrodes which then creates the cascade effect of "thermal runaway." While solid-state batteries are not immune to shorting out, they are much less likely to catch fire because of it.

It's important to note that statistics from the National Transportation Safety Board have shown that EVs catch fire less often than internal combustion engines, and vehicles most prone to fire are hybrids simply because they contain two flammable liquids – gasoline and electrolytes – not because rechargeable batteries are inherently more dangerous.

## Solid-state in action

Today's solid-state prototypes have significantly reduced charging times, the latest by Toyota offering a lightning-fast rate of only ten minutes to reach a 745-mile range (and a promised 932 miles in the second generation).

This is a first for Evs--comparable to filling up at the pump. By contrast, Tesla's Supercharger network, the largest of its kind, offers about 200 miles of range on a 15-minute charge. Toyota plans to mass-produce these batteries for industry use by 2027.

With the rush to get solid-state batteries into vehicles for road testing and purchase sooner, automakers can either reduce the price of the battery or the car around it. Affordability in the interim may have to come from engineering focused on facilitating battery mass production, reducing general vehicle fabrication costs, or only putting superior solid-state batteries in high-end car models.

Innovative technologies like giga-casting (aluminum die-casting of a few larger, more simplified parts) and vehicle redesigns focused on production efficiency are all being attempted to bring the cost of solid-state batteries down closer to competing with lithium-ion batteries.

## Fatal flaw, surprising solution

Solid-state's most persistent and baffling disadvantage has been that (until now) these ideal batteries seemed to randomly and prematurely short out due to a persistent gremlin – dendrites.

Named after the Latin word for branches, dendrites are soft, microscopic lithium tendrils that begin branching from one electrode to the other during the process of charging and discharging, penetrating even ceramic-based electrolyte, eventually bridging the gap and short-circuiting the cell.

Heavy research and funding has gone into understanding the how and why solid-state batteries fail this way, from in-depth investigations at the Faraday Institution at Oxford to research teams from Brown University and MIT, paid for by the U.S. National Science Foundation, the U.S. Department of Defense, and the U.S. Department of Energy.

Research published in the journal Joule, led by Massachusetts Institute of Technology Professor Yet-Ming Chiang, finally demonstrated that it is not a mysterious electrochemical process but mechanical stresses that cause the problem. Due to compression, stress fractures formed in the solid electrolyte, allowing the electrode's lithium to permeate the material.

"Metal penetration through solid electrolyte separators is a key challenge facing high energy-density batteries, and to date much attention has been directed toward the properties of the separator material through which the metal penetrates," said Paul Albertus, an associate professor of chemical and biomolecular engineering at the University of Maryland.

Eventual separation of the hard layers in solid-state batteries still

TOYOTA MOTOR COMPANY

Toyota plans to first install solid-state batteries in hybrid vehicles that are slated to be ready for sale as early as 2027.

NASA's SABERS team is developing solid-state batteries that are lightweight, powerful, and safe enough for future electric aircraft, such as this aerial vehicle for urban transportation.

NASA

threatens their efficiency and shortens their lifetimes, and "stack pressure" is often applied to battery cells to reinforce them, essentially compressing the material in the direction perpendicular to the battery's plates—like a panini sandwich.

That pressure was discovered to exacerbate dendrite-induced failure, creating directional cracks like ready-made corridors for the lithium to travel between electrodes. Meanwhile, pressure induced along the plane of the plates caused the dendrites to change direction, never grounding against the opposite electrode.

Rather than capitalizing on this breakthrough, the study has been shared.

"I would say this is an understanding of failure modes in solid-state batteries that we believe the industry needs to be aware of and try to use in designing better products," said MIT Professor Yet-Ming Chiang

This is an elegant solution, but with so many solid-state battery companies developing proprietary products with their own challenges, it won't be the only one.

## A problem of scale

Researchers have spent years looking for the right combination of materials, with each fabrication settling on a unique range of problems and solutions, none of which have been easy to put into mass production due to the complexity of creating batteries in a lab as opposed to a factory floor.

Most production difficulties surround the delicate forms that the new chemistries take. Manufacturers are used to working with powders and slurries, but pure lithium works best as a thin, free-standing foil.

"It has the consistency of wet tissue paper," said Solid Power CEO Doug Campbell about scaling up the process. "And so you can imagine when you're making literally kilometers of material, it gets very tricky."

Hedging their bets, the technicians at Solid Power favor an anode mostly made of silicon, which has its own issues of retaining shape under stress.

As battery size increases, tiny imperfections can be compounded, threatening structural integrity as they are scaled up. EV-sized cells don't do as well as they should in the cold, and battery life declines too quickly after repeated fast charging; all problems in ramping up mass production.

Lithium-ion battery makers have advanced over the past 30 years, constructing massive factories and better automation that has driven down costs.

"We don't want to reinvent all the machines," said Shirley Meng, a battery scientist at the University of Chicago. "We want to drop in the solid-state and only make small tweaks. That's the most ideal situation."

## Getting in on the action

Solid Power, in collaboration with Ford and BMW, has already started pilot production of a battery design that reuses existing processes and equipment in Colorado that will produce about 15,000 batteries per year – small beans next to gigafactory-scale lithium-ion battery production but is still ambitious in its timing.

The goal, according to Campbell, is to start delivering cells to its automotive partners for road testing by the end of the year, then pass the baton to one of its North American gigafactory-owning

partners like SK Innovation.

Hyundai has said it plans to mass produce solid-state batteries by 2030 in a partnership with Factorial Energy, a Massachusetts-based developer of solid-state battery technology. The joint development agreement will integrate Factorial's technology into future vehicles and is drop-in compatible for easy integration of existing lithium-ion battery manufacturing infrastructure.

Both the Stellantis Group and Mercedes have also invested in Factorial, targeting competitive solid-state battery production for 2026, intent on integrating the technology into a limited series of vehicles in the next five years.

Honda expects to release a solid-state-powered EV during the second half of this decade and is testing polymer buffer layers to protect against dendrite formation. The automaker has teamed up with GM and Sony for further research and development.

Nissan is working toward mass production of solid-state batteries by 2028 and aims to launch its first EV powered by a battery developed in-house from a pilot plant up and running in Yokohama, Japan, as early as 2024.

Automotive Cells Co – a venture between Mercedes-Benz, Stellantis, and TotalEnergies – is also developing solid-state batteries with Taiwan-based battery maker ProLogium Technology.

Volkswagen, in collaboration with U.S. battery startup QuantumScape (backed by Bill Gates), plans to build new factories rather than try to retool ones already out there in order to fabricate ceramic and lithium-based battery design that requires a proprietary set of manufacturing processes.

The team is currently building a pre-pilot production line in California to deliver batteries to automakers for road testing within the next year. QuantumScape has published that it also has contracts with five additional yet-to-be-disclosed EV makers.

NASA is also very much involved with electrifying advanced air mobility, from air taxis and ride shares to robotic package deliveries and airborne emergency medical services. NASA's Solid-state Architecture Batteries for Enhanced Rechargeability and Safety (SABERS) have substantial government and industry interest. This still-developing sulfur selenium battery tech is stackable, 40% lighter, discharges 15% faster for serious power, works under twice the temperature extremes of liquid-filled counterparts and is less affected by rapid changes in pressure which occur during takeoff and landing.

In 2022, industrial manufacturer Hitachi Zosen launched a solid-state battery claiming one of the highest capacities in the industry and a wider operating temperature range. Japan Aerospace Exploration Agency announced the solid-state batteries had properly operated in the vacuum of space, powering camera equipment on the International Space Station.

## Room for improvement

Battery production costs still need to be reduced by simpler, more streamlined engineering and chemistry. (Solid-state batteries still cost roughly three times more than standard lithium-ion.)

Challenges to widespread adoption and scalability include durability as size increases, maintaining lower interface resistance, and extension of battery lifetimes (polymer electrolytes are more flexible and headed in this direction).

For any battery to perform well, electrodes and electrolytes must maintain complete surface area connectivity. Compared to liquid electrolytes, layered designs lose efficiency too quickly under normal wear and tear and need resilience to counteract warping, pressure, and cracking.

When electrolytes are changed from liquid to solid, manufacturing processes that differ from lithium-ion batteries are unavoidable. For example, solid-state batteries based on sulfides require facilities with strict moisture control. The key will be in creating high-efficiency new processing facilities or adaptive designs for facilities already in existence.

Additionally, due to compositional similarities, the process of recycling solid-state batteries should adapt as much as possible to the Li-ion battery industry's preexisting recycling infrastructure.

Solid-state batteries have had the support needed to fast-track the creation of a robust market, and the industry has quickly made exceptional progress in research and development. This technology is the key to getting the world to net zero faster, not only through electrified vehicles on the road but across the seas, skies, and even outer space. DMN


Refined powders from lithium batteries recycled by Redwood Materials. From left to right, graphite, copper foil, mixed metal sulfate, mixed metal hydroxide, and lithium carbonate.
TOYOTA MOTOR NORTH AMERICA

# Battery metals require responsible recyclers

## Age of wasteful consumerism is gone, time to shore up recycling

By A.J. ROAN
DATA MINE NORTH

**SEPARATING YOUR PLASTICS,** paper, metals, and food waste has generally been a personal choice throughout most of modern recycling history. However, current demand for resources predicts we won't have enough to support net-zero carbon emissions by 2050. Hence, now is the best time for consumers to become educated and self-determined with their buying power, manufacturers to begin considering recycling as part of the initial design, and a new circular economy that resurrects a tradition that supported America at its lowest point.

Before industrialization, recycling was practiced in ways far removed from what it is known as today – and people were much better at it.

If the elbows in a shirt wore out, you'd take the sleeves off, turn them inside out, and presto: new shirt. If a dress went out of style, you added new buttons or sent it to the dressmaker to fashion a trendier frock.

People would whittle down their possessions, maximizing the use of each item until nothing remained but rags and scrap.

"Before there was municipal solid waste disposal, stuff would pile up in your house if you didn't reuse it," said Susan Strasser, author of Waste and Want: A Social History of Trash. "In addition, people who made things had an understanding of the value of material goods that we don't have at all. Literally, if everything you wore, sat on, or used in your house was something you made or your mother or uncle or the guy down the street made, you had a very different sense of value of material goods."

With the present global transition to low-carbon energy and transportation, this offers a once-in-a-century opportunity and maybe a planet-saving practice to rethink how products are manufactured in a direction that favors reuse and reignites a way of life that carried Americans through the dark times of depression and war.

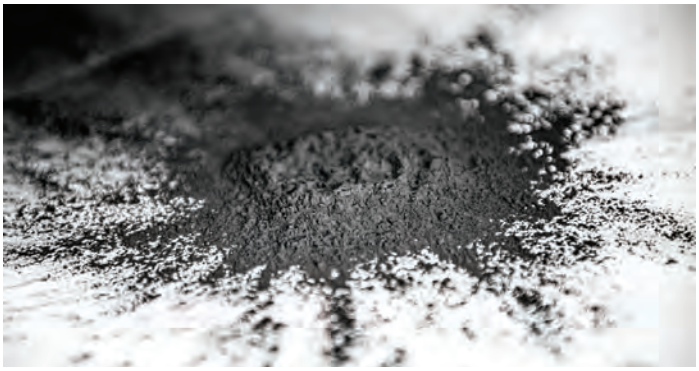
### It was tradition

When garbage pickup started in the late 19th century, many cities separated reusable trash from garbage designated for the landfill. Just like today, workers sorted via conveyor belts as early as


LI-CYCLE HOLDINGS CORP.

LI-CYCLE HOLDINGS CORP.

**Above: Left to right: Christopher Moon, Li-Cycle's Arizona Spoke Plant Manager; Ajay Kochhar, Li-Cycle's co-founder and CEO; Secretary Jennifer Granholm, U.S. Department of Energy; Mark Kelly, U.S. Senator for Arizona, gather at Li-Cycle's lithium-ion battery recycling facility in Gilbert, Arizona. Upper right: Left to right: Li-Cycle co-founder and CEO Ajay Kochhar speaking with Canadian Prime Minister Justin Trudeau, European Commission President Ursula von der Leyen, and Li-Cycle co-founder and Executive Chairman Tim Johnston at the company's spoke facility in Kingston, Ontario. Right: ABTC's first integrated recycling facility is designed to process over 20,000 metric tons of battery feedstock material per year.**



AMERICAN BATTERY TECHNOLOGY COMPANY

1905. Afterward, cities sold reusable trash to industries while people saved their food waste to feed their livestock.

But by the 1920s, source separation was no longer happening and not much was being recycled apart from metal at scrapyards.

"But really there was a relatively short period of time that people didn't recycle," Strasser said.

It truly was a short period, as America soon faced its hardest economic downturn in history – the Great Depression. With no choice but to stretch material goods as far as they could go, and sometimes farther, reuse of what you had was the only option.

And that frugality and ingenuity carried the United States straight on into World War II – while devastating and horrific, mobilization of the people toward a common goal is what lifted the fog.

Millions of men and women joined the armed forces, and even larger numbers went to work in well-paying defense jobs. Yet all those who lived through the Great Depression carried with them a knack for scavenging.

It wouldn't be until closer to the 1960s that the first recycling programs began to link with people's concern for the environment.

"As the environmental movement begins to take hold on a national scale, recycling was seen as a personal manifestation of helping the environment," said Martin Melosi, author of Fresh Kills: A History of Consuming and Discarding in New York City. "There was a sense of connection to the environment."

Beyond the do-gooders, though, most people in the throw-away society of the time didn't think too much about preservation or reducing use – until landfills started filling up in the 1970s.

"Landfilling was the most popular form of disposal after World War II," Melosi said, and recycling was a way to reduce the tipping point. "It takes things out of the waste stream, preserving landfill space. So recycling begins to have an economic and strategic role, different from just saving the environment."

Due to the potential ramifications of overfull landfills, it prompted recycling to be viewed through an economic lens. Although not as altruistic as most would hope, leaning into the system can sometimes be a solution – and recycling of all things electronic and reclaiming decades of resource waste for future clean energy is looking to be pretty viable, even if it is to support capitalism instead of the environment.

Although, in this case, it will do both.

## Planned obsolescence

"They don't make them like they used to," perhaps a familiar expression as vehicles, appliances, devices, clothing, equipment, gear, tools, etc., just feel like they don't have the same longevity or durability as the ruggedly built, made-to-last products of yesteryear.

While there is some truth to this, it is certainly not across the board, as technology has improved to the point where many of today's products are in a league of their own. However, entering into the digital age, a concept that not many are aware of has perhaps crept up to bite.

Planned obsolescence – this describes the practice of designing and manufacturing products intended to break or degrade quickly or become obsolete in the short to mid-term. The general idea behind this is to encourage sales of new products and upgrades.

Although banned in some countries, there are no laws against planned obsolescence in the U.S.

However, is this really the case?

The answer: yes, but not how one might think. Beyond the simple caricature of greedy companies wantonly fleecing their customers, another impetus for quickly replacing goods rests at the feet of the consumers as well.

To an extent, planned obsolescence is an inevitable consequence of businesses giving people the goods they desire. In this way, it serves as a reflection of a ravenous consumer culture that industries did create for their benefit, yet are hardly alone in doing so.

"Fundamentally, firms are reacting to the tastes of the consumers," said Judith Chevalier, a professor of finance and economics at Yale University. "I think there are some avenues where [businesses]

are kind of tricking the consumer, but I think there are also situations where I might put the fault on the consumer."

So, if some responsibility lay at the feet of consumers, if there was ever a time to impose buying power, it would be now. And to help enforce sustainability, especially concerning recycling, the European Council initiated groundbreaking legislation that takes the wastefulness from consumers and imposes manufacturers to be the bigger man.

### EUs battery recycling law

Announced early July, the Council of the European Union adopted a new regulation that could possibly cut out the concern for planned obsolescence by strengthening sustainability for batteries, in particular, portable batteries often found in consumer products like cell phones.

Toward the ultimate goal of a circular economy, this landmark legislation sets a precedent in the standards that should be taken in a recycling-led GDP. These include:

• The regulation sets targets for producers to collect waste portable batteries (63% by the end of 2027 and 73% by the end of 2030) and introduces a dedicated collection objective for waste batteries for light means of transport (51% by the end of 2028 and 61% by the end of 2031).

• The regulation sets a target for lithium recovery from waste batteries of 50% by the end of 2027 and 80% by the end of 2031, which can be amended through delegated acts depending on market and technological developments and the availability of lithium.

• The regulation provides for mandatory minimum levels of recycled content for industrial, SLI batteries and EV batteries. These are initially set at 16% for cobalt, 85% for lead, 6% for lithium and 6% for nickel. Batteries will have to hold recycled content documentation.

• The recycling efficiency target for nickel-cadmium batteries is set at 80% by the end of 2025 and 50% by the end of 2025 for other waste batteries.

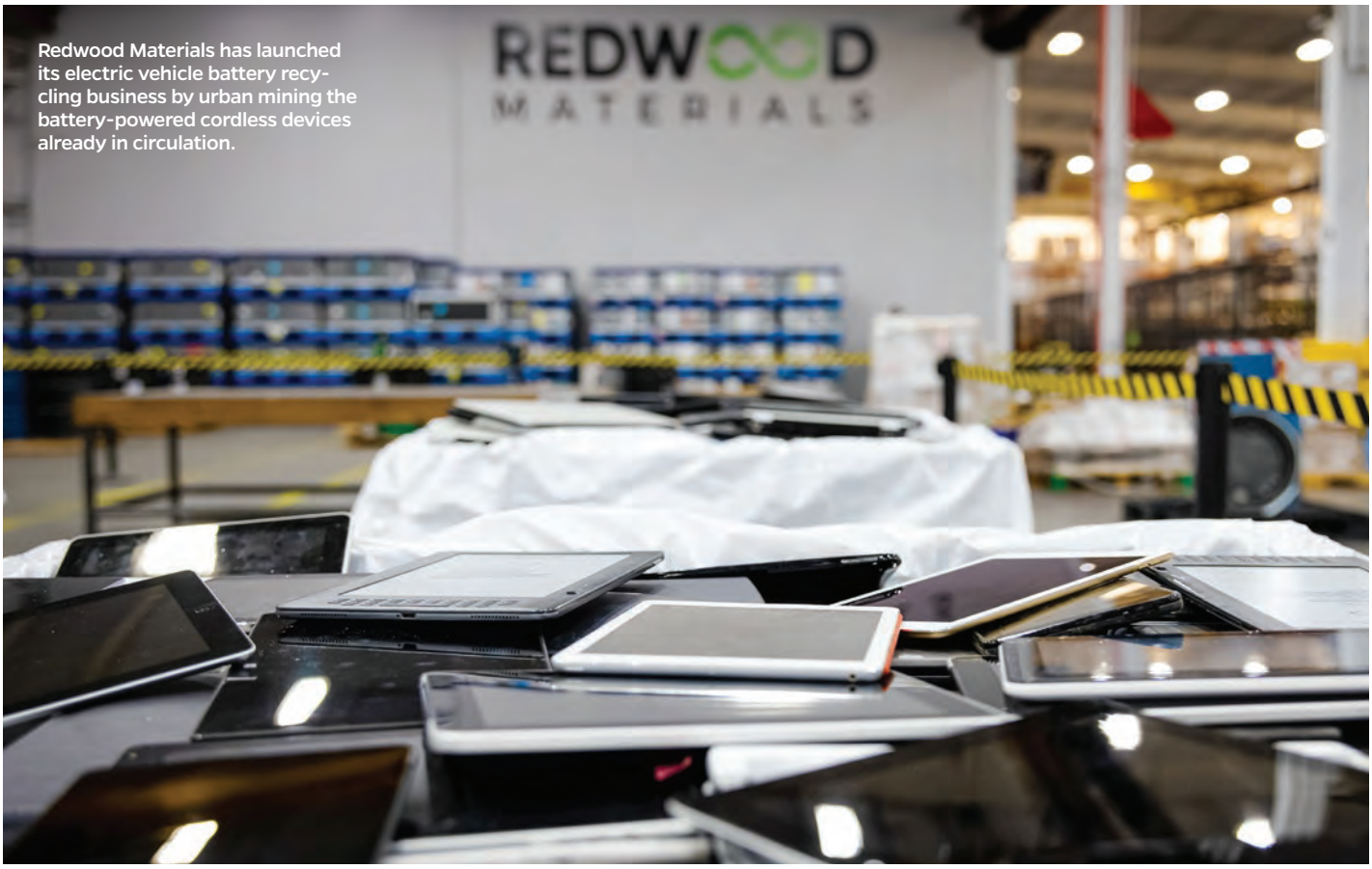
• The regulation provides that by 2027 portable batteries incorporated into appliances should be removable and replaceable by the end-user, leaving sufficient time for operators to adapt the design of their products to this requirement. This is an important provision for consumers.

The last point is perhaps the most impactful and has made several headlines for its precedent toward manufacturers such as Apple that have been notorious for phones becoming more and more difficult over the years to repair – favoring full replacement.

And with phones costing upwards the same as laptops, it is not a sustainable long-term model.

Hence, to curb waste and inefficient resource use in the form of new models each year, the EU legislation aims to steer manufacturers back to a time when fully realized products that can stand the test of time will be built once again.

The regulation of the European Parliament and the Council will apply to all batteries, including all waste portable batteries, electric vehicle batteries, industrial batteries, starting, lightning and ignition (SLI) batteries (used mostly for vehicles and machinery) and batteries for




Redwood Materials has launched its electric vehicle battery recycling business by urban mining the battery-powered cordless devices already in circulation.

REDWOOD MATERIALS

light means of transport (e.g., electric bikes, e-mopeds, e-scooters).

## The battery recycling front lines

In North America, a handful of companies have broken away from the rest with completed facilities that have begun to recycle and produce battery-grade materials.

With no legislation yet that matches the stringent regulations like those of the European Parliament, these companies have taken it upon themselves to fill in for a market that is sure to become the keystone for a circular economy.

Founded in 2017 by Tesla co-founder JB Straubel, Redwood Materials Inc is a forward-thinking company that has been ahead of the curve in recycling as a means to meet the monumental challenge of supplying the demand for lithium-ion battery material in the West.

Having already formed partnerships with Ford Motors, Volkswagen, and Toyota, it is evident that what Redwood can provide has enticed these legacy automakers, especially considering they are at the forefront of the demand. The initial frontrunner of battery recycling in North America, Electra Battery Materials Corp., has already successfully shipped its first deliveries of recycled nickel-cobalt from its refinery complex north of Toronto, Canada.

Coming a long way since its acquisition of the Yukon cobalt refinery in 2017, this company has quickly gained traction as the likely leading provider of the critical minerals and metals that will fuel a zero-carbon future.

Settling into an already fully permitted processing facility in Ontario that once operated between 1996 and 2015, over the following years, the company has steadily advanced into an operation that will be capable of producing roughly 5,000 metric tons of battery-grade cobalt sulfate each year.

Located less than 400 miles (640 kilometers) from Great Lakes manufacturing towns such as Detroit and Buffalo, this rail-accessible refinery has garnered strong interest from battery and automotive manufacturers seeking a secure and sustainable supply of this controversial battery metal.

With the first mover advantage of the first cobalt sulfate refinery in North America, Electra has quickly carved itself a position in the low-carbon energy and transportation transition for years to come. And with plans to expand into alternate recycling technologies, such as solvometallurgy, as well as black mass material recovery, Electra is well on its way to helping the West break away from its reliance on the East.

Another big name in the burgeoning EV battery recycling sector, Li-Cycle Holdings Corp. made headlines multiple times with visits from Heads of State, first with U.S. Senate Majority Leader Chuck Schumer, D-NY, then U.S. Secretary of Energy Jennifer Granholm and U.S. Senator Mark Kelly, D-AZ, later Canadian Prime Minister Justin Trudeau and President Ursula von der Leyen, then finally Arizona Governor Katie Hobbs.

With such an all-star lineup, there must be something to this battery recycler. Established similarly in Ontario, Li-Cycle has thus opened facilities in New York and Arizona, with many more to follow that will centralize its recycling technologies through its Spoke and Hub method.

The spokes are the distributed network of how it takes in all types of lithium-ion batteries and transforms them into an inert product that is shredded and separated. In comparison, the hub is the centralized operation. With 12 possible spokes to every hub, Li-Cycle will convert black mass directly to battery-grade chemicals

and use a non-thermal process that purifies the materials to transform them back into ready battery-grade materials for future lithium-ion batteries.

In March, Li-Cycle was conditionally approved through the U.S. Department of Energy's Advanced Technology Vehicles Manufacturing loan program for a loan of $375 million to expand its recycling efforts. This follows a mid-2022 $200 million loan from Glencore.

With support from federal and private entity giants, its technology has proven to be something worth exploring.

Keeping in lockstep, American Battery Technology Metals has also drawn the interest of dignitaries. White House representatives from the National Science Foundation and Office of Science and Technology Policy, the site visit was to highlight the company's capabilities and progress.

Founded in 2011, ABTC began with a few mining claims out of Nevada. Much like Redwood, the company was spun out by a former Tesla employee seeking a means of providing lithium-ion batteries for the famed EVs; it turned out that this foresight proved astute.

Recognizing the severity of delivering domestic supplies of the lithium, cobalt, nickel, and manganese needed not just in EVs but in solar panels, wind turbines, and battery storage systems, ABTC broadened its business to more than just primary battery metals manufacturing but also into lithium-ion recycling.

With ample funding due to its promising recycling technology, a ready-made facility for the company to begin operations, a pre-commercial building under construction, and an agreement for pre-purchase of its future product, ABTC is proving its foresight was not just a one-off and is preparing to provide America with ABTC battery materials.

As a pioneer in lithium-ion battery cathode recycling, British Columbia-based RecycLiCo Battery Materials Inc. (previously American Manganese Inc.) has quickly grasped the dilemma of future battery materials scarcity and has developed an incredible solution that allows its patented RecycLiCo process to upcycle old cathodes to the new chemistries being used in today's batteries powering EVs.

>> *"As the environmental movement begins to take hold on a national scale, recycling was seen as a personal manifestation of helping the environment."*

*–Martin Melosi, author of* Fresh Kills: A History of Consuming and Discarding in New York City

Peer-reviewed, third-party analyzed, and stringently verified, each assessment has continued to verify the legitimacy of RecycLiCo's recycling technology.

In one of its numerous assessments, London-based and globally recognized sustainability consultancy Minviro Ltd. determined that RecycLiCo's process resulted in a 35% reduction in CO2-equivalent emissions for nickel-manganese-cobalt precursor production and a 74% reduction in lithium hydroxide production compared to the raw mining of these materials.

In addition to its emission-reduction capabilities, the process itself has been found to be extremely effective, retaining 99% of the lithium, nickel, manganese, and cobalt from the resulting black mass of ground-up batteries.

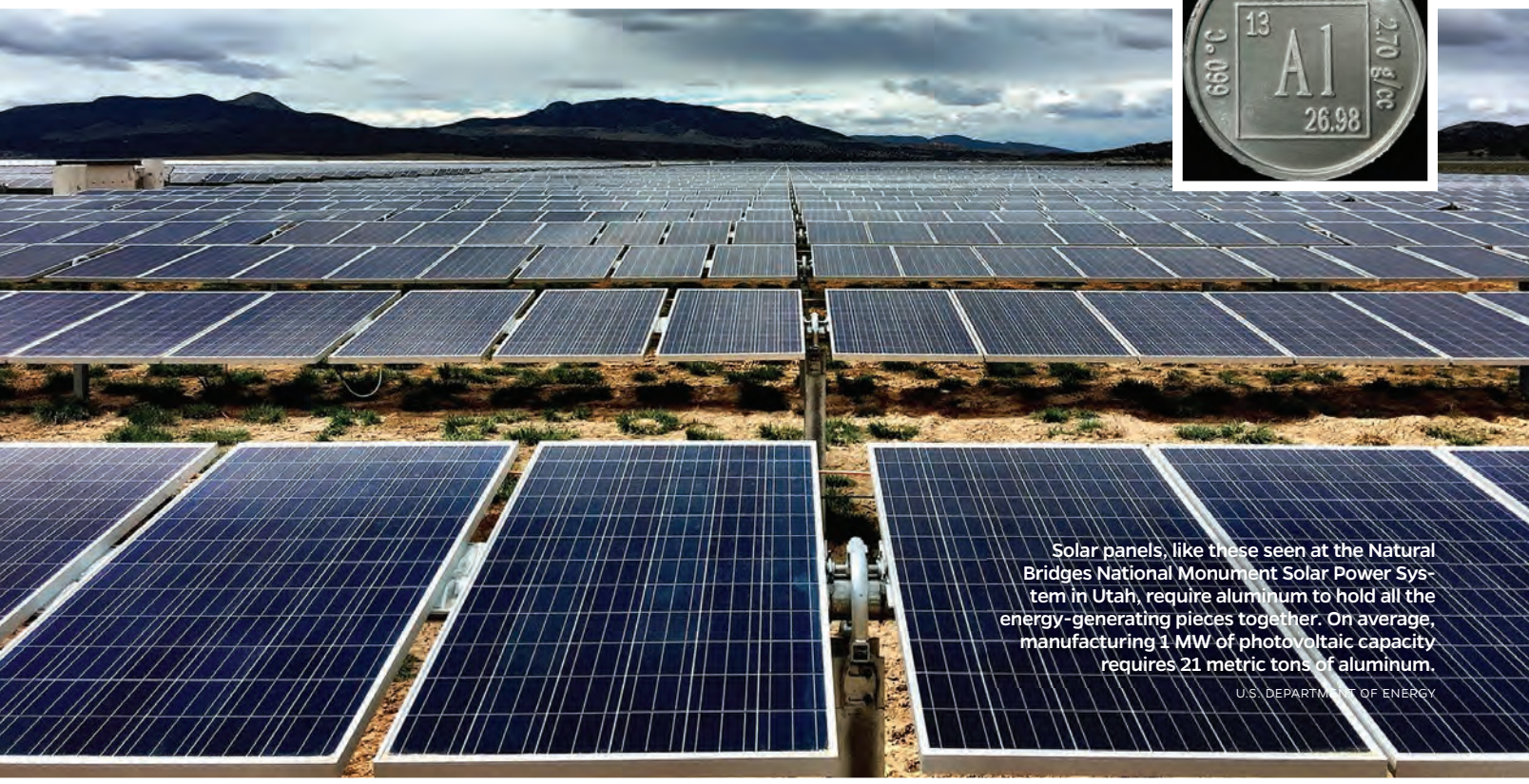
Furthermore, through scanning electron microscopy imagery, it has been shown that example products from RecycLiCo's recycling share the same high-quality technical specifications – such as particle morphology, size, and distribution – found in conventional lithium-ion battery cathode precursor materials produced from mined raw materials.

As the trailblazers of a future where your current phone, laptop, television, monitor, and everything else electronic can be taken in and the elements they are made from reformed into EVs and the batteries that power them, these companies are charting the way for a next generation of industry.

And hopefully, the effects of recycling will be felt individually rather than on the scale of just "helping the environment" when that clearly had never truly been the case. DMN

ADOBE STOCK


Recycling is seen as a key piece of a truly sustainable transition to electric vehicles and clean energy.




Solar panels, like these seen at the Natural Bridges National Monument Solar Power System in Utah, require aluminum to hold all the energy-generating pieces together. On average, manufacturing 1 MW of photovoltaic capacity requires 21 metric tons of aluminum.

U.S. DEPARTMENT OF ENERGY

# Aluminum caught in a green energy paradox

## Government largesse goes to demand as supply suffers setbacks

By A.J. ROAN

DATA MINE NORTH

**ALUMINUM HAS BEEN CLASSIFIED** as critical by the United States, European Union, Canada, and even China. At first glance, one may wonder how such an ubiquitous metal could possibly be critical. The answer is simply that aluminum is so widely used that supply, if endangered, could devastate an economy.

In 2020, the World Bank identified aluminum as a "high-impact" and "cross-cutting" metal in all existing and potential green technologies.

In spite of this, due to high energy costs, particularly in Europe, smelters have been closed or forced to curtail output resulting in the lowest run-rate of aluminum in a century.

Further still, this projected decline did not result in aluminum making it onto the EU's Critical Raw Materials Act (CRMA), legislation that was announced by President Ursula von der Leyen during her 2022 State of the Union speech, where she called to address the EU's dependency on imported critical raw materials by diversifying and securing a domestic and sustainable supply of critical raw materials.

"This is why today I am announcing a European Critical Raw Materials Act. We know this approach can work," said von der Leyen during her address. "Five years ago, Europe launched the Battery Alliance. And soon, two third of the batteries we need will be produced in Europe. Last year I announced the European Chips Act. And the first chips gigafactory will break ground in the coming months. We now need to replicate this success."

The CRMA covers a subset of the EU's critical minerals list, with particular focus on battery metals like lithium, nickel, cobalt, and manganese and magnet inputs such as boron and rare earths.

Copper made this list as an enabler of all things electric, but aluminum and zinc did not, which is a striking omission given the recent shrinkage of European production capacity.

On the U.S. side of things, the government has tried via import tariffs to support domestic producers of aluminum but with little lasting success.

Even with the Inflation Reduction Act and its generous subsidies for this domestically-sourced metal, this has proved ineffective in addressing aluminum's green energy paradox.

## Looming aluminum deficit

According to the International Aluminium Institute, Western European primary aluminum production has been sliding since 2017, but Russia's invasion of Ukraine and the resulting spike in energy prices have accelerated the downtrend.

Falling by 12.5% in 2022 and slipping further so far this year, the region's annualized production averaged 2.7 million metric tons in the first four months of 2023. West European run rates exceeded 4.5 million metric tons just 15 years ago.

U.S. primary metal production has been falling since 2019, with two out of seven domestic smelters fully curtailed and three operating at reduced capacity, according to the United States Geological Survey.

The USGS estimates domestic production was running at just 52% capacity at the end of 2022, with import dependency growing to 54% from 41% in 2021.

This decline in Western production contrasts with the rise of China, which now accounts for roughly 58% of global production of aluminum, a sort of dominance that has triggered major re-shoring efforts in other critical minerals such as lithium and rare earths and whose effects the West may feel with recent restrictions on gallium and germanium.

While the U.S. market can lean on Canada for primary aluminum supply, Europe has traditionally relied on Russia, now a highly problematic long-term partner.

Even factoring in greater recycling, the world will need another 25 million metric tons of primary production capacity if it expects to meet emissions reductions goals, according to the International Aluminium Institute.

## Green tech framework

Aluminum is used directly in all new energy technology, particularly in solar power, where it accounts for 85% of photovoltaic (PV) components in the form of frames that hold the PV panels together.

This lightweight metal's future demand profile is also tied to the accelerating roll-out of electric vehicles, with automakers using more aluminum to lighten their cars for greater energy efficiency out of the already critical batteries that are driving this whole frenzy in the first place.

In a report commissioned by European Aluminium, automotive consultancy Ducker Carlisle returned its findings: the amount of aluminum used in European cars increased by 18% from 174 kilograms (384 pounds) in 2019 to 205 kg (452 lb) in 2022.

The report further predicted this trend would continue, with the average aluminum content projected to increase from 205 kg in 2022 to 237 kg (522.5 lb) by 2026 and 256 kg (564 lb) by 2030.

While the future should be bright for the West's beleaguered aluminum smelters, particularly as Europe and the U.S. channel government funding down green accelerator paths, however, will supply meet that demand?

According to the Mineral Commodity Summaries 2023, last year, the supply chain for aluminum suffered setbacks at each stage. Fresh from the ground bauxite to alumina refining, then further processing into aluminum.

For Europe, the conflict between Russia and Ukraine led to the closure of a 1.7-million-ton-per-year alumina refinery in Ukraine, while high energy costs caused a 600,000 tpy alumina refinery in Romania to temporarily shutter.

Additionally, a 1.7 million tpy alumina refinery in Spain had to curtail its production by up to 60%.

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**Bauxite is a sedimentary rock with a relatively high aluminum content. It also happens to be the world's main source of aluminum and gallium.**

Further along the chain, several primary aluminum smelters and aluminum product manufacturers throughout Europe announced shutdowns or partial curtailments.

Although production of aluminum continues to find bumps in the road, aluminum powerhouses are doing what they can to keep up the supply of aluminum needed for green technologies, but the support they receive is paling in comparison to demand.

## Green energy paradox

A key problem surrounding the flow of materials for an electric-powered future is government largesse is bolstering aluminum's demand rather than supply.

The Inflation Reduction Act, the CHIPS Act and the Infrastructure Investment and Jobs Act will channel US$1.25 trillion to green energy sectors, according to U.S. think-tank SAFE's Center for Strategic Industrial Metals.

Since all green energy applications, from solar to wind to EVs, need aluminum, the combined effect appears to accelerate demand.

However, the amount of funding available to aluminum's supply side in the form of manufacturing credits and grants for domestic processing comes in at slightly more than 10% of the demand side – US$126 billion, according to SAFE.

Carbon is at the heart of aluminum's green energy paradox. Both a critical material for enabling economy-wide decarbonization and one of the highest-emitting industrial metals, particularly from smelters powered by fossil fuels, many heavy industrial metals face similar issue.

The advent of superheating metal to change its composition broke Mankind away from rudimentary metallurgy; the next phase is concentrating that energy in a way that reduces emissions, and therein lies the problem.

"By setting the decarbonization conditionality for supply-side support and simultaneously increasing demand across multiple sectors, the United States entraps itself in this cycle," SAFE contends.

In other words, simply providing funds for smelters to reduce

their direct emissions won't solve the problem unless there is simultaneous investment in greening their power supply.

The carbon problem is compounded in Europe by the proposed Carbon Border Adjustment Mechanism (CBAM), which "will do more harm than good," according to Emanuele Manigrassi, European Aluminium's Senior Manager of Regulatory Affairs.

"We expect the CBAM to only increase the costs of production and consumption of aluminium in Europe, with no reduction in global emissions," Manigrassi wrote in a May 17 blog.

Energy, particularly green energy, holds the key to preserving a primary aluminum production base in both Europe and the United States.

U.S. policy in its current form "threatens to leave its own aluminium behind" by neglecting to recognize the metal's green power paradox, SAFE warns.

Many industry insiders believe that both U.S. and European sectors need a more holistic approach from policymakers—with a first step being to include aluminum in the CRMA.

Europe's primary aluminum sector is facing an existential crisis, according to Europe Aluminium's general secretary Paul Voss, speaking at a forum jointly hosted with Eurometaux in February.

"If the political signal is this material isn't very important, of course you could just let it go to the wall," he said.

But if Europe wants to stay in the business of making primary aluminum, "just put us on the damn list."

## Hydrogen calcination

While incentives could certainly catalyze supply, companies like Rio Tinto and Sumitomo Corp. have taken it upon themselves to play an UNO reverse card – incentivize supply, through green aluminum.

If the top issue is emissions from heavy carbon-producing production, just change the entire process and remove emissions entirely or at least substantially.

Announced in mid-2021, Rio Tinto partnered with the Australian Renewable Energy Agency (ARENA) to study whether hydrogen could replace natural gas in alumina refineries to reduce emissions.

Initiating a A$1.2 million (US$778,404) feasibility study – equally funded by ARENA through a A$580,000 (US$376,229) grant – into using clean hydrogen to replace natural gas in the calcination stage of producing alumina at the Yarwun alumina refinery in Gladstone, Queensland, the study must have had some promising results as the top aluminum producer announced in July its plans to deploy a demonstration plant in collaboration with partner Sumitomo Corp.

To be built in Australia, at Yarwun, the A$111.1 million (US$73.9 million) pilot project will be a first-of-its-kind deployment of hydrogen calcination in the world.

Co-sponsored by ARENA, which contributed A$32.1 million (US$21.3 million) to the venture, the project is designed to reduce pollution from alumina refining, which accounts for roughly 3% of Australia's greenhouse gas emissions.

As the world's largest exporter of alumina, Australia relies on its production, which contributes approximately A$7.5 billion (US$5 billion) to the nation's gross domestic product.

ARENA CEO Darren Miller said the pilot is an important step in the development of hydrogen calcination and the decarbonization of the alumina production process.

"This world-first pilot looks to prove a promising technology for decarbonizing one of our most emissions intensive industries," he said.

ARENA's Alumina Decarbonisation Roadmap, or Alumina Roadmap, published in 2022, identified hydrogen calcination as one of four technologies that could reduce emissions from Australia's alumina refineries by up to 98%.

The renewable energy agency has been investing in projects to reduce emissions from the aluminum value chain since 2021. This includes providing funding to Alcoa, an American-based aluminum producer out of Pittsburgh and the eighth largest in the world, to investigate electric calcination and trial mechanical vapor recompression, two further technologies identified in the Alumina Roadmap.

The final part of the Bayer process, the most widely used method to transform bauxite into alumina, calcination, requires a lot of energy. Heating up hydrated alumina from the preceding precipitation stage at temperatures up to 1,100 degrees Celsius (2,012 degrees Fahrenheit) to form anhydrous alumina, the primary fuel to reach this temperature has typically been natural gas.

With a demo plant underway, the carbon-contaminated steam from fossil fuel-powered calcination could become what hydrogen power is most notable for, pure water molecules.

Once constructed, Sumitomo will own and operate the electrolyzer – the device that catalyzes alumina into aluminum – at Rio Tinto's site and supply the hydrogen to Rio Tinto directly. With a production capacity of more than 250 metric tons of hydrogen annually, Rio Tinto will conduct a series of tests of the prototype hydrogen calciner under different operating conditions to validate suitability and performance.

If successful, the project will demonstrate the viability of hydrogen calcination and pave the way for adoption at scale across other alumina refineries, according to ARENA.

"Having already backed an encouraging feasibility study, we're excited to be working with Rio Tinto and Sumitomo Corporation to build on that success and trial hydrogen calcination in the field," said Miller. "If this pilot project is successful, it could be a game changer for Australian alumina production, paving the way for deployment across the industry, and underscoring the importance of low-cost green hydrogen to decarbonize our largest industrial emitters. ARENA will continue to support projects at this scale as we develop other larger programs, such as Hydrogen Headstart." DMN


The primary commercial use for germanium is in fiber optic cables that provide high-speed data streaming to billions of people worldwide.

ADOBE STOCK

# China plays gallium, germanium pieces

## The 2010 rare earths trap could offer insights into strategy

By SHANE LASLEY
DATA MINE NORTH

**AS THE WHITE HOUSE CONTINUES** to dole out hundreds of billions of dollars to position America as the global leader in clean energy and digital technologies, Beijing initiates a strategy to put America in check with the global economy equivalent of pawns.

These pawns in the technology chess match between the U.S. and China are gallium and germanium, a pair of semiconductor metals used to make the computer chips essential to every facet of modern life.

Before all the major news outlets posted headline stories covering China's plans to restrict exports of gallium and germanium to "safeguard national security interests," most people outside of the realms of mining and chipmaking had never heard of these tech metals.

The reason for this ambiguity is both metals are rare and rarely used outside of the tech and green energy sectors.

According to the U.S. Geological Survey, roughly $39 million of germanium and $225 million of gallium metal and gallium arsenide semiconductor wafers were used by American manufacturers during 2022.

While these numbers pale in comparison to industrial metals like copper ($33 billion) and zinc ($4 billion), gallium and germanium have tremendous market leverage due to their uses in high-tech and green energy products.

Gallium serves as a primary ingredient in semiconductors vital to next-generation smartphones, telecommunication networks, automobile electronics, light-emitting diodes (LEDs), thin-film solar panels, and medical devices.

Germanium is a powerful ingredient in fiber optics, night vision devices, triple-layered solar panels, and transistors for classic and

quantum computers.

Various semiconductor products made from both critical tech metals are used to make the computer chips used in virtually every electronic device. The scarcity of new vehicles for sale on showroom floors in the U.S. during and after the COVID pandemic is an example of how a lack of these computer chips can stall the global economy.

"China has hit the American trade restrictions where it hurts," Peter Arkell, chairman of the Global Mining Association of China, said in July.

This isn't the first time China wrought its critical metals dominance as a pain-inflicting pawn against those standing in the way of Chinese interests.

In 2010, the Middle Kingdom employed a similar strategy to leverage its near-complete monopoly of the production of rare earths, a suite of tech metals that also have large global economy implications that belie their relatively small market time. At that time, China demonstrated that it could hurt outside interests and bolster its own by both turning off and on the rare earth spigot.

A review of China's rare earths playbook could be useful to companies and governments hoping to build non-Sino gallium and germanium supply chains.

## CHIPS Act oversight?

To avoid future disruptions of supplies of the computer chips critical to U.S. manufacturing, supply chains, and national security, President Joe Biden signed the CHIPS Act in 2022. This law allocated $52.7 billion for American semiconductor "research and development, science and technology, and the workforce of the future to keep the United States the leader in the industries of tomorrow, including nanotechnology, clean energy, quantum computing, and artificial intelligence."

This includes $39 million in chipmaking incentives in the U.S., which comes with the caveat that companies taking advantage of these subsidies are restricted from doing any significant transactions with China or "any other foreign country of concern" for 10 years.

The act, however, does not address the need for semiconductor raw materials like gallium and germanium. Commodities analysts and foreign policy experts see China's export limitations on this pair of metals as a counter to a U.S. technology gambit that includes the CHIPS Act and some Washington lawmakers calculating a move toward further computer chip export restrictions to China.

"Gallium and germanium are chess pieces in a geopolitical game of enormous proportions," Christopher Ecclestone, a mining strategist at the consulting firm Hallgarten & Company, told Washington, DC-based Foreign Policy.

What makes these tech metal pawns so powerful for China is the U.S. currently relies on imports for 100% of its supply of gallium and more than 50% of its germanium.

According to the U.S. Geological Survey, China produced 98% of the world's gallium during 2022 – Russia came in second at around 1%. When it comes to germanium, 54% of America's imports also came from China.

Reuters recently reported that the U.S. does not currently have any government stockpiles of gallium to fall back on, which makes the situation more troubling for high-tech manufacturers.

"Gallium and germanium are just a couple of the minor metals that are so important for the range of tech products and China is the dominant producer of most of these metals," said Arkell. "It is a fantasy to suggest that another country can replace China in the short or even medium term."

## Chinese REE playbook revisited

Given gallium and germanium's outsized impacts on the tech sector and, by extension, the global economy, the mining sector and Western governments are scrambling to diversify the supply of these semiconductor metals away from China.

This anticipated push to break into small markets dominated by a country that has direct control over the spigot, however, is wrought with challenges.

A look back at China's 2010 rare earths playbook offers some insight into the difficulties associated with trying to break into the markets for Sino-controlled critical minerals.

When China turned off the rare earth spigot in 2010, the prices for this suite of 15 tech elements skyrocketed. For example, the price for a kilogram of the rare earth europium rose from US$475 per kilogram in 2008 to a peak of US$3,800 in 2011.

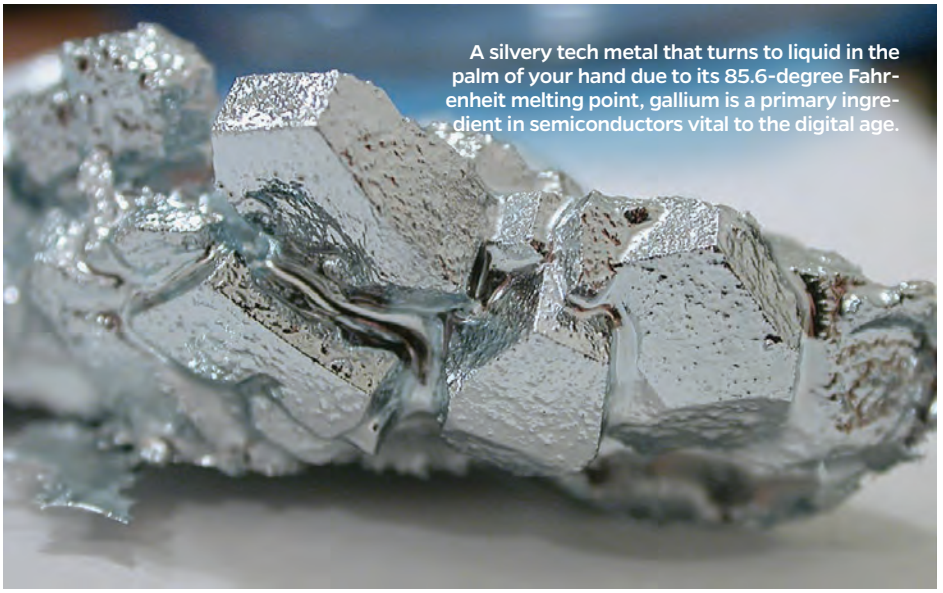
This rise in rare earth prices made the economics of mining rare earths outside of China compelling, and companies around the globe quickly began advancing REE projects.

A couple of years later, however, China dumped large quantities of rare earths onto global markets, which sent prices for this suite of tech metals tumbling below 2009 levels, a devastating blow to many upstart rare earths projects and companies.

Molycorp, an American company that set out to reopen the Mountain Pass rare earths mine in California's Mojave Desert, was among the victims of the price fluctuations caused by the ebb and flow of China exports.

The ups and downs at Mountain Pass have long been tied to China's rare earth sector. This Southern California mine rose as the dominant supplier of rare earths in

FOOBAR PHOTOGRAPHY



A silvery tech metal that turns to liquid in the palm of your hand due to its 85.6-degree Fahrenheit melting point, gallium is a primary ingredient in semiconductors vital to the digital age.

the 1960s, a position the mine held until China decided to control the sector. Unable to compete with a country with lower labor costs and environmental standards, Mountain Pass was shuttered in 2002.

Championed as the company that would reopen Mountain Pass and provide America with a domestic alternative to China for rare earths, Molycorp stock rocketed from around US$10 per share in 2009 to US$74 a share one year later. By 2015, however, the American rare earth miner's stock had plummeted to less than US10 cents per share, and the company was forced to file for Chapter 11 Bankruptcy.

The rise and fall of Molycorp was a common theme for REE-focused companies around the globe. Whether by providence or design, this provided China with an opportunity to acquire distressed rare earth assets outside of its borders.

A state-owned Chinese mining company even made a bid to buy a controlling interest in Lynas Corp., which mines rare earths in Australia and operates one of the only REE processing facilities outside of China. Australia's Foreign Investment Review Board, however, stepped in and stopped the deal, citing concerns that the purchase could result in restricted supplies to non-Chinese buyers.

China-based Shenghe Resources Holding Co. did manage to nab a minority holding in MP Materials, a company that arose from the ashes of Molycorp and reopened the Mountain Pass mine in 2019.

While the 2010 rare earths strategy is likely not the only play in China's book, it was effective and could prove to be tough to defend when it comes to establishing gallium and germanium supply chains outside of the Middle Kingdom.

## Superior tech metals

What makes gallium and germanium powerful pawns in China's technology chess match with the U.S.? The answer lies in the technologies this pair of superior semiconductor metals enable.

Gallium, for example, is the primary ingredient in gallium arsenide and gallium nitride semiconductors vital to the digital age.

"The development of gallium arsenide as a direct band-gap semiconductor in the 1960s led to what are now some of the most well-known uses of gallium – in feature-rich, application-intensive, third- and fourth-generation smartphones and in data-centric networks," USGS penned in a report on critical minerals and metals.

As a superior semiconductor, Gallium nitride is increasingly being used for the integrated circuits going into faster and more reliable telecommunications devices, servers, laptop adapters, and even onboard chargers for electric vehicles.

"GaN offers higher power density, more reliable operation and improved efficiency over traditional silicon-only based solutions," Texas Instruments wrote about its portfolio of integrated circuits using gallium nitride power transistor technology.

The advent of 5G-capable telecommunication networks is pushing demand for this silvery tech metal that liquefies in the palm of your hand even higher.

"Owing to their large power-handling capabilities, high-switching frequencies, and higher voltage capabilities, GaN-based products, which historically have been used in defense applications, are used in fifth-generation (5G) networks, cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets," USGS wrote.

While germanium has powerful semiconductor properties similar to gallium, this critical metal's superior optical qualities – transparency to the infrared electromagnetic spectrum, ability to be formed into glass, exceptionally high refractive index, and low chromatic dispersion – are what drive the highest demand for this metalloid.

> >> *"Gallium and germanium are chess pieces in a geopolitical game of enormous proportions."*
>
> *–Christopher Ecclestone*

"The major use of germanium worldwide is for fiber-optic systems, whereby germanium is added to the pure silica glass core of fiber-optic cables to increase their refractive index, minimizing signal loss over long distances," USGS inked in a germanium fact sheet.

The International Energy Agency estimates that 5 billion people will be using the Internet by 2025, a roughly 40% increase over the 3.6 billion in 2018. This increase of people streaming movies, games, and other large data files at lightning-fast speeds continues to drive the demand for more fiber-optic cables and the germanium that goes in them.

Infrared imaging devices used by the military, law enforcement agencies, and increasingly in the private sector are another major driver of demand for the optical qualities offered by germanium.

## Critical North American byproducts

With China's hand on the gallium and germanium spigot, American tech manufacturers and the Pentagon are looking for alternatives.

Following China's July announcement, a Pentagon spokesperson said, "The (Defense) Department is proactively taking steps using Defense Production Act Title III authorities to increase domestic mining and processing of critical materials for the microelectronics and space supply chain, including gallium and germanium."

Germanium, which is already produced in the U.S. and Canada, will be the easiest to replace.

Like many of the minerals and metals deemed critical to the U.S., germanium is not mined as a primary commodity. Instead, the metalloid is recovered as a byproduct from mining zinc and other base metals.

"As a byproduct metal, the supply of germanium is heavily reliant on zinc production," according to the USGS.

Teck Resources Ltd.'s Red Dog Mine in Alaska, the second-largest producer of zinc on Earth, is also a globally significant source of germanium.

In the U.S., germanium was also recovered as a byproduct of zinc mining and refining in Tennessee, as well as recycled from industry-generated scrap at a refinery in Oklahoma.

"Based on an analysis of zinc concentrates, U.S. reserves of zinc may contain as much as 2,500 tons of germanium," USGS inked in its 2023 Mineral Commodity Summaries.

As operator of both Red Dog and Trail Operations – a refinery in southern British Columbia that processes the concentrates from Red Dog and other zinc mines – Teck is the largest germanium producer in North America.

The high-quality germanium products produced at Trail are used in fiber optic cables, high-speed computer chips, quantum com-

puter transistors, solar cells, light-emitting diodes (LEDs), and night vision goggles, to name a few.

Nyrstar, which is owner and operator of the zinc refinery in Tennessee, announced in mid-2022 that it is investing $90 million into adding gallium and germanium recovery circuits to the operation. According to the company, the new circuits could recover as much as 40 metric tons of germanium and 30 metric tons of gallium per year.

"Nyrstar is engaging with state and federal government to secure support for the project, which would enable germanium and gallium to be produced domestically for the first time, helping to secure the US supply chain for these critical minerals for the defense, electronics and energy sectors," Nyrstar spokesperson Gytha Steenvoorden told local news outlet Clarksville Now.

### Gambit, trap, or blunder?

Whether China's advancement of its gallium and germanium pawns is part of a full-on gambit that includes other critical mineral chess pieces that it dominates – graphite, indium, and niobium, to name a few – or is tempting the West into a trap, the move requires a response.

Kevin Klyman, a U.S.-China research analyst at Harvard's Belfer Center, believes Washington lawmakers see the move as an opening for a counter-offensive to break America's dependence on China for critical minerals.

"My read is that the US government is happy about this move," he said. "This forces suppliers to diversify their supply of gallium, germanium, and other critical minerals, and it will cause markets to reinterpret the value of mining in North America and other regions."

Tech metals dealers in Europe and the U.S. say they have plenty of stores to fill any short-term gaps in supply and the ability to produce more outside of China.

TRADIUM, a specialty metals trader based in Germany, says it "has healthy inventories of technology metals and rare earth elements stockpiled in its high-security warehouse in Frankfurt."

Gallium, germanium, indium, and platinum group elements are among the tech metals the company has in its inventory.

In the U.S., American Elements not only has healthy stores of gallium and germanium but informed the tech industry that it has the capacity to increase production of both semiconductor metals essential to missile systems, computer chips, and solar panels at its plant in Salt Lake City, Utah.

A quick web search shows that the Los Angeles-headquartered specialty metals dealer sells more than 100 different forms of both gallium and germanium alloys, nanomaterials, semiconductors, and other products.

Following China's announcement that it would be restricting exports of this pair of specialty metals, American Elements said it will "significantly expand production of gallium and germanium from its Salt Lake City plant" to ensure that it can continue to supply customers with this pair of critical metals.

Given American Elements' apparent ability to meet shortfalls, the company's CEO, Michael Silver, believes China's gallium and germanium move to be a blunder.

"U.S. domestic supply will not be impacted by this short-sighted decision of China," he said.

The Los Angeles-based dealer and manufacturer of critical mineral products says it will continue to supply its Chinese customers from its manufacturing facilities in Asia. DMN

PEGGY GREB, U.S. DEPARTMENT OF AGRICULTURE

Clockwise from top center: praseodymium, cerium, lanthanum, neodymium, samarium, and gadolinium.

# Rare earths future hangs in the balance

## Keeping up with EV demand creates oversupply of non-magnet REEs

By SHANE LASLEY
DATA MINE NORTH

**A GROWING IMBALANCE** in the supply and demand for rare earths is creating a challenge for the companies that produce this suite of technology elements and an opportunity for the scientists seeking ways to leverage their unique properties in new and intriguing ways.

While it is true that the global transition to zero-carbon energy and transportation is creating new rare earths demand that threatens to outstrip the global supply, the real disparity has more to do with which of these elements are being demanded by the automotive, green energy, and tech sectors – and, maybe more importantly, those that are not.

While rare earths are often talked about as if they are one commodity, in reality they are a suite of 15 elements that each have unique characteristics that have been enabling and enhancing technologies over the past 60 years.

"It is critical to understand individual REE, instead of dealing with them as a group," the International Renewable Energy Agency inked in a 2022 report on rare earths.

Since being used in the first color television sets in the 1960s, scientists have continually found new ways to apply the seemingly magical properties of this suite of tech metals.

These discoveries have evolved into ultra-high-definition flat screens that allow us to stream our favorite shows in more than 1 billion colors; more robust fiber optic signals that help ensure the show does not need to buffer in the middle of a dramatic scene; high-fidelity speakers that are small but fill the room with cinema-quality sound; portable X-ray machines that do not need electricity; the world's most accurate atomic clock; and the list goes on.

While every rare earth has some unique quality to offer, there are five – neodymium, praseodymium, terbium, dysprosium, samarium, gadolinium, and holmium – with powerful magnetism that is hard to resist when it comes to creating a high-tech future powered by clean energy.

This group of magnet rare earths is used in motors that efficiently transform electricity into motion in the growing line of electric vehicles traveling global highways, wind turbines that transform a

gentle breeze into low-carbon electricity to charge those EVS, MRI machines that create detailed images of organs and tissues, and a plethora of other modern wonders.

The ambitious transition to e-mobility and clean energy is creating enormous demand for this subset of the suite of rare earth elements, which is creating an oversupply of other REEs that are mined alongside their more popular counterparts.

"The fact that different REE are co-produced while the markets for them are diverging means that some are scarce while others are oversupplied. This divergence will grow in the coming years," IRENA penned in its report.

## EVs drive a balance problem

The growing rare earths divergence is underscored by Stellantis' mid-2023 agreement to buy rare earths from a future mine at NioCorp Developments Ltd.'s Elk Creek critical mineral project in Nebraska.

Stellantis is not interested in all 14 rare earths found in the Elk Creek deposit. Instead, the global automaker best known in North America for its Dodge, Jeep, and Ram brands entered into an agreement with NioCorp for future supplies of four magnet REEs – neodymium, praseodymium, dysprosium, and terbium – it will need for its expanding line of EVs.

"By working with partners like NioCorp, we are taking important steps, with the aim of decarbonizing mobility and ensuring strategic supplies of raw materials necessary for the success of the company's global electrification plans highlighted in our Dare Forward 2030 strategy," said Maxime Picat, chief purchasing and supply chain officer at Stellantis.

While having a preliminary commitment from Stellantis is bolstering NioCorp's endeavors to monetize the magnet rare earths at Elk Creek – an American Midwest mine project that is better known for its rich stores of niobium, titanium, and scandium – the company will need to look elsewhere for buyers of the other REEs also found in the deposit.

This is a common theme across the rare earth sector. There are no neodymium, praseodymium, dysprosium, or terbium mines – just rare earth mines with some mix of the 14 stable REEs.

This is resulting in stockpiles of less demanded rare earths stacking up as mining and processing facilities endeavor to keep pace with the clean energy transition.

This growing overabundance of some REEs and undersupply of others is creating a widening spread in the rare earth prices. In August, a kilogram of 99.9% cerium oxide was selling for about US$2.50, while 99.5% neodymium and praseodymium oxides were selling for roughly US$50/kg, and 99.99% terbium oxide was fetching around US$590/kg.

This means that the value of a deposit is not determined so much by the total rare earth oxides it contains as the quantities of highly demanded rare earth oxides it has to offer.

At the Mountain Pass Mine in California, for example, lanthanum and cerium make up more than 80% of the total rare earths contained in the deposit. The value of the only mine operating in the U.S., however, lies in the neodymium and praseodymium, which only make up approximately 16% of the total rare earths but roughly 80% of the value of the REEs in the Mountain Pass deposit.


Dysprosium and terbium are high-valued rare earths used to improve the heat resistance and durability of REE magnets used in EVs, wind turbines, and industrial applications.

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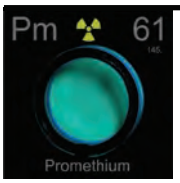
# Rare earth elements and how they are used


**Lanthanum** A B G – This lightest of the rare earths is used in making specialized glass for high-quality camera and telescope lenses. Lanthanum-nickel alloys have multiple renewable energy applications that include hydrogen fuel cells, hydrogen storage, and electric vehicle batteries. The nickel metal hydride batteries in each Toyota Prius hybrid car contain roughly 10 pounds of lanthanum.


**Cerium** A G C L – This element is a major ingredient of the mischmetal alloy in flints for cigarette lighters and is often used for polishing high-quality optical surfaces. Cerium oxide is also often used as a catalyst in self-cleaning ovens; as an ingredient to reduce carbon monoxide emission in catalytic convertors; and in the carbon-arc studio and projector lighting used by the film industry.


**Praseodymium** A M L G – While it is primarily used in high-strength alloys for aircraft engines, praseodymium is increasingly being used to create durable high-power magnets essential to electric vehicles and wind turbines. This element is also used in the core of carbon-arc studio and projector lighting; as a signal amplifier in fiber optic cables; and as a yellow colorant for glass, enamels, and ceramics.


**Neodymium** M La – A namesake of the high-power neodymium-iron-boron magnets that go into electric vehicles, wind turbines, medical imaging equipment, computer hard drives, and high-quality audio equipment (microphones, headphones, speakers, and acoustic pick-ups). Neodymium-doped garnet crystals are also used in lasers for skin cancer treatment, hair removal, and to cut and weld steel.




**Promethium** R – Extremely rare and unstable in nature, it is estimated that less than 600 grams of promethium occur in the Earth's crust at any given time. Promethium produced in labs is used in atomic batteries for pacemakers, guided missiles, and radios. Light given off by this truly rare element's radioactive decay can be captured by a device similar to a solar cell to produce electricity.

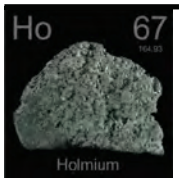

**Samarium** M La – Highly resistant to demagnetization, even at high temperatures, samarium-cobalt magnets are used in high-performance motors, audio equipment (microphones, headphones, speakers, and electric guitar pick-ups), quartz watches, and camera shutters. Samarium is also used in crystals for optical lasers, infrared absorbing glass, and as a neutron absorber in nuclear reactors.


**Europium** L P – This element is widely used to create blue and red phosphors for televisions and computer monitors, as well as producing a more natural white light for fluorescent bulbs. Coincidentally, europium's distinct red glow under UV light is leveraged for anti-forgery marks on Euro banknotes. This rare earth, which is excellent at absorbing neutrons, is also used in nuclear reactor control rods.


**Gadolinium** A P La – This rare earth has unusual metallurgical properties. As little as 1% gadolinium can greatly improve the workability, as well as heat and oxidation resistance, of iron and chromium alloys. This element is also used as green phosphor in televisions; in gadolinium-yttrium garnets for microwave applications; computer storage discs; and as neutron absorber in the core of nuclear reactors.


**Terbium** M P – High-temperature magnets made with terbium are used in EVs and wind turbines. A terbium alloy that expands or contracts in the presence of a magnetic field is used to make a SoundBug, which creates a vibration that turns any flat surface it is placed on into a speaker. Terbium is also used as a green phosphor in televisions, and terbium green is one of three colors used for trichromatic lighting tech.

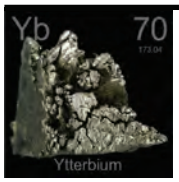

**Dysprosium** M L – One of the strongest magnetic elements and highly resistant to demagnification at high temperatures, dysprosium is used to increase the durability and reduce the weight of neodymium magnets for EV motors and wind turbine generators. Dysprosium iodide is also used to produce an intense white light in the medium source rare earth lamps used by the film industry.




**Holmium** M La – With the highest magnetic strength of any element on the periodic table, holmium is used to create the strongest artificial magnetic fields. This property is used primarily in magnetic flux concentrators, which can intensify and direct a magnetic field. Holmium-doped garnets are used in lasers for eye surgery and can destroy cancerous tumors with minimal damage to the surrounding tissue.

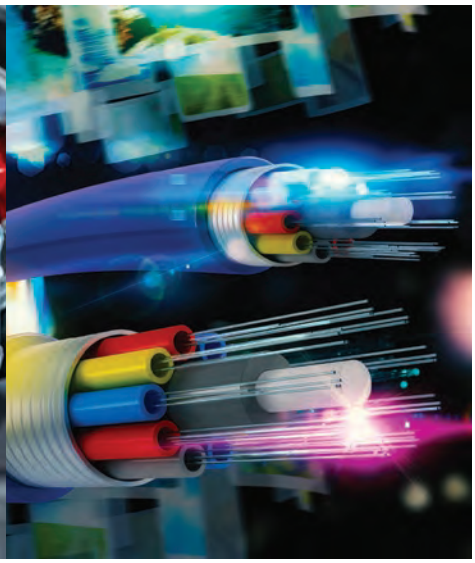

**Erbium** La G – Amplifying the signal of fiber optic cables carrying data over long distances is a major use for erbium. This element, along with vanadium, is used in alloys to increase the pliability of metals. Garnets in lasers used for tattoo removal and other skin resurfacing, a pink colorant for sunglasses and imitation gems, and infrared absorbing safety glasses for welders are other uses for this rare earth.


**Thulium** La – Like many of the other rare earths, thulium is used in precision lasers for surgical applications. When bombarded by neutrons, thulium becomes radioactive thulium-170 (128.6-day half-life), which ejects soft gamma radiation that can be used for portable X-ray devices. Euro banknotes also take advantage of this element's blue fluorescence under UV light for counterfeit prevention.




**Ytterbium** A – Ytterbium clocks are the most stable atomic clocks in the world. This element is also used to improve the strength of stainless steel. Because its electric resistance increases by an order of magnitude under high stress, ytterbium is used in gauges to detect earthquakes or underground explosions. This rare earth is also a radiation source for portable X-ray machines that do not need electricity.


**Lutetium** C R – Rarer and more expensive than most rare earths, lutetium has few uses outside of research. Isotopes of this rare element with very long half-lives are used in cancer treatment and for age dating meteorites. The most common use of lutetium, however, is as a catalyst for petroleum cracking in refineries. Research indicates that lutetium-ion clocks have the potential to be the most accurate on Earth.



ADOBE STOCK

Maintaining a rare earths balance while delivering the magnet REEs needed for clean energy and high-tech is a growing issue for the mining sector.

"The rare earth balance problem continues to be an issue for U.S. miners," the U.S. Department of Energy penned in a paper on the rare earths supply chain.

## A hidden opportunity

The clean energy-driven rare earths imbalance, however, may be creating a hidden opportunity for technology and material scientists exploring new ways to utilize special properties of the elements on the periodic table for the betterment of modern living.

And just because a rare earth does not have magnetic qualities does not mean it does not have exceptional properties waiting to be unlocked.

"There are literally hundreds of uses for rare earths – they are unique materials, almost alchemistical magic," said Michael Silver, CEO of American Elements, a Los Angeles-based distributor of rare earths and thousands of other advanced materials.

Materials scientists are continually growing this list with new discoveries that utilize the seemingly magical qualities of rare earths.

DOE has tackled the rare earth balance problem head-on by tasking its national labs to find new uses for oversupplied rare earths. Here is a rundown of REE balance projects being carried out under this endeavor:

Accelerated Alloy Deployment and Rapid Assessment – Ryan Ott, a materials scientist and engineer at the Ames National Laboratory, is working to enhance usage of overly produced rare earths, such as cerium, and decrease the usage of critical elements, such as neodymium. This work includes investigating 3D printing and other technologies to create cost-effective, high-performance magnets and high-temperature aluminum alloys that use abundant REEs. Given the impending need, the Ames team is working to accelerate the timeframe that these REE balance technologies are developed.

Cerium Gettering of Copper and Iron in Aluminum Alloy Recycling – Also led by Ott, this project is exploring the improvement of energy efficiency and economics of aluminum recycling by using abundant rare earths, such as cerium. The Ames Lab research team has demonstrated that the addition of small amounts of cerium to aluminum increases alloy tolerances to impurities, such as copper and iron, and improved overall corrosion resistance. These additions also allow for lower-quality aluminum to be used in the production of high-value alloys, reducing the need for both energy and cost-intensive high-purity aluminum additions. Research continues in opportunities that would compound cerium deterioration benefits with the focused addition of aluminum.

Al-REE Alloy Development for Advanced Manufacturing (AL-REE

ADAM) – Hunter Henderson, a materials engineer at the Lawrence Livermore National Laboratory, is leading a team seeking to correct the rare earth imbalance by developing high-volume and high-value applications for cerium. This project demonstrates that metal 3D printing of aluminum-rare earth element alloy forms an internal nanostructure that is resistant to degradation. The team found that this 3D-printed aluminum-cerium alloy outperformed the aluminum currently used in aerospace and defense components. These alloys also demonstrate enhanced thermal performance, which adds to their value and the cerium that goes into them. The team will scale up for demonstration and continue to improve performance at room temperature strength.

DOE's Advanced Materials and Manufacturing Technologies Office and Critical Materials Institute, which are leading this work, says the superior aluminum-cerium alloys are helping tackle the rare earths balance problem "by finding new ways to use cerium that will shore up market demand for an abundant REE and create more value from domestic rare-earth mining operations."

### More balanced Wyoming deposit

As the EV revolution unfolds, deposits with a mix that leans more heavily toward magnet rare earths are more valuable and will contribute less to the REE balance problem.

One U.S. deposit enriched with the rare earths needed for high-tech and the energy transition is found at Rare Element Resources Ltd.'s Bear Lodge project in northeastern Wyoming.

According to the most recent calculation, Bear Lodge hosts 18 million metric tons of measured and indicated resources averaging 3.05% (1.2 billion pounds) rare earth oxides. Not only is this deposit large and high-grade, but it has healthy quantities of critical REEs.

Neodymium and praseodymium, the two main ingredients in the magnets for EV motors and other high-tech devices, make up 22.8% of the total rare earths contained in the Bear Lodge deposit. Four other magnet REEs – dysprosium, gadolinium, samarium, and terbium – make up another 5.2%.

While cerium and lanthanum still comprise the bulk of the rare earths by weight, about 70%, the ratio of non-magnet to magnetic REEs in this deposit is high.

Rare Element's plans to develop a mine and processing facility in Wyoming has drawn support from both the public and private sectors.

In 2021, DOE provided the company $21.9 million for a plant that demonstrates an innovative rare earths processing and separation technology pioneered by General Atomics.

General Atomic affiliate Synchron, which owns a 54.8% stake in Rare Element, processed 1.1 metric tons of Bear Lodge ore through a pilot plant in Germany to produce 13.6 kilograms of neodymium-praseodymium oxide at commercial grade.

Rare Element says the innovative process has been further optimized to offer environmental and cost advantages over other REE separation technologies.

The company is now scaling this technology up with a demonstration plant in Upton, Wyoming, that will process roughly 900 metric tons of ore averaging around 10% rare earth oxides stockpiled at Bear Lodge.

In addition to the DOE grant, the Upton demo plant received backing from the Wyoming Energy Authority, which awarded the company $4.4 million for the project.

"Given that Wyoming is home to one of the highest-grade rare earth deposits in North America, we felt supporting Rare Element Resources' demonstration plant in Upton was vital," said Wyoming Energy Authority Executive Director Glen Murrell.

The combination of a high-grade mine and separation plant will put Wyoming on the map as a hub for essential rare earths.

"We understand, as does Wyoming, that our project will serve as a cornerstone for the rare earth industry in Wyoming and America while providing a venue for worker training in rare earth processing and separation," said Rare Element Resources President and CEO Brent Berg.

With the demo plant slated to start in the next year, Rare Element can begin looking at a commercial operation that fully unlocks the larger rare earth potential at Bear Lodge.

The current Bear Lodge deposit would support a mining operation that could produce roughly 6,800 metric tons (15 million lb) of rare earth oxides annually over a 45-year mine life, according to a prefeasibility study completed in 2014. DMN

Nuclear energy comes from tiny uranium pellets that are stacked vertically into long metal tubes and then slowly turned into the clean energy that powers roughly 19% of America.

NUCLEAR ENERGY AGENCY

# Semantics strays uranium energy criticality

## Definition aside, nuclear energy will be necessary for net zero

By A.J. ROAN

DATA MINE NORTH

**POWERING NEARLY 10%** of the world's energy needs and roughly 20% of America for over 50 years, nuclear energy is a highly controversial power provider that ticks all the boxes for zero-emission electricity. Much like most contemporary fuels, running these reactors takes something dug from the earth – uranium.

In 2017, the United States Geological Survey was charged with identifying which minerals and metals are critical to the U.S. Its original list of 35 critical minerals, finalized in 2018, included uranium. However, an updated and expanded list of 50 critical minerals published in early 2022 omitted this material necessary for zero-carbon nuclear energy.

Evidently, striking uranium from the original list had less to do with the mineral's proposed criticality and more to do with semantics.

Under the Energy Act of 2020, a "critical mineral" is defined as a non-fuel mineral or mineral material essential to the economic or national security of the U.S., as well as the supply chain, which is vulnerable to disruption. Critical minerals are also characterized as serving an essential function in the manufacturing of a product, the absence of which would have significant consequence for economic or national security.

"Uranium was not evaluated because the Energy Act of 2020 explicitly excluded 'fuel minerals' from the definition of a 'critical mineral,'" the USGS explained in a FAQ sheet associated with the list of critical minerals.

While grammatically accurate, there are those that believe that given our heavy dependence on adversarial nations (historically Russia) for this mineral vital to the U.S. military and zero-carbon energy, it should be ranked high on the list of critical minerals.

"Our uranium import dependence is a case study in how our vital domestic minerals supply chains have atrophied to levels that result in a dire national security risk. We are home to the world's largest nuclear navy and fleet of nuclear power plants, significant

uranium reserves, and yet we import virtually all of the uranium we use – half of which comes from Russia, Kazakhstan and Uzbekistan," said National Mining Association President and CEO Rich Nolan. "We must immediately address this glaring vulnerability and source the uranium on which nuclear power functions domestically to prevent this key energy source from being weaponized against our economy."

With uranium meeting all the other critical minerals criteria, simply striking "non-fuel" from the definition would make this nuclear fuel eligible to be put back on the list.

Nevertheless, it has been over a year since the USGS published its official critical minerals list, and even with possible bipartisan legislation through the "Critical Minerals Classification Improvement Act" which would require the USGS to reevaluate the criticality of uranium and other non-fuel minerals for inclusion on an updated list, the bureaucracy does not change the reality of the future risk of this fuel mineral.

A fuel assembly, usually several meters long, can spend years in a reactor, generating immense amounts of low-carbon electricity.

FRAMATOME

## Uranium breakdown

Discovered in 1789 by German chemist Martin Klaproth, who named it after the planet Uranus, which had been discovered just eight years prior, Uranium is found naturally as ore dug up from the earth.

While Hollywood and pop culture have caused perceptions surrounding this mineral to be seen as glowing in an eerie greenish or bluish hue (which isn't untrue, although not as exaggerated as radioactive materials emit particles that excite other elements, which then causes a faint light), this weakly radioactive material is actually a silvery, white metal found in seawater and all three broadly defined groups of rocks: igneous, sedimentary, and metamorphic.

Also often seen as some mythical material that's nearly impossible to find due to its rarity, uranium is actually more abundant than precious metals, being nearly 40 times more common than silver and 675 times more common than gold, according to numbers from the 97th edition CRC Handbook of Chemistry and Physics.

For reference, the Earth is estimated to house about 0.075 parts per million silver, and about 0.004 ppm gold, while uranium is about 2.7 ppm.

Furthermore, uranium has a unique trait that makes it quite easy to find compared to most of its elemental brethren, its radioactivity. Despite its abundance, however, the major challenge for commercial uranium extraction is to find areas where concentrations are adequate to form an economically viable mine.

The heaviest of all elements, uranium has three naturally occurring forms or isotopes – U-238, U-235, and U-234 – which are just variations of the atomic nucleus based on the total number of protons and neutrons. Of those specific isotopes, U-235 is most often sought after because its atoms are more easily split apart to create the chain reaction necessary for nuclear fission. However, despite the earlier statement of its ease of discovery, setting aside economic viability, U-235 is relatively rare at just over 0.7% of natural uranium, according to the Energy Information Administration.

Setting aside the politics of its place on the critical minerals list, with only 54 commercially operating nuclear power plants containing 93 power reactors across 28 states, this small number powers roughly one-fifth of the entire country and has done so for over half a century.

So how much uranium is needed to fuel these plants, in particular, the ideal fissile material U-235? About 27 metric tons, or 18

million fuel pellets housed in 50,000 fuel rods, is required for a single 1,000-megawatt-electric capacity pressurized water reactor.

What, then, makes it purportedly critical? Aside from generating about 20% of the power in America, the same isotopic material U-235 is needed in nuclear weaponry.

## Uranium list controversy

In 2019, George Washington University's Institute for International Science and Technology Policy published a statement for a hearing on uranium mining and its criticality.

Titled "Critical Minerals: Why is Uranium on the List?" The statement gives a brief history of the beginnings of the criticality dispute of uranium and reiterates that it does not belong on the list.

"The supply of minerals, like energy, should be judged secure when it is reliable, adequate and affordable. Such secure supplies could be domestically or internationally sourced. There are few reputable analysts who would suggest that Canada or Australia might suddenly cut off supplies of uranium to the United States for political or economic reasons. Utilities in the United States purchased 42% of their uranium in 2018 from Canada and Australia, which are two of the top three producers of uranium; Australia has 30% of the known recoverable reserves," the statement said in its concluding section.

Initiated by the Trump administration's direction to develop a strategy to secure reliable supplies of critical minerals at the end of 2017, the Secretary of the Interior at the time began the process of identifying critical minerals.

The argument for its inclusion was the non-fuel aspects of uranium – nuclear weapons.

However, the list published in 2018, which included uranium, was opened to public comments, and more than a third of the 588 comments objected to its inclusion because it is a fuel source.

Hence, it was struck from the list in 2022 as it is not considered critical per the definition.

The reasoning for defensive supply risk was apparently countered by the already substantial reserves contained within the United States.

The total U.S. highly enriched uranium inventory, as of 2013, was calculated at 531.2 metric tons, enough to make more than 23,000 nuclear weapons, which was reasonably suggested that no additional production would be necessary (as of 2019, there are approximately 15,000 nuclear weapons on Earth, and America alone holds almost half that number).

When it comes to zero-carbon nuclear energy, however, American power plants lean heavily on imports for their fuel needs.

According to the EIA, the United States imports nearly 95% of its uranium needs from other countries – 35% from Kazakhstan, 15% from Canada, 14% from Australia, 14% from Russia (as of 2021), 10% from five different countries, 7% from Namibia, and the remaining 5% being "homegrown."

With industry experts, analysts, and insiders, it is certainly known the dependence on 95% of the fuel needed to power 19% of America's energy is anything but a slight risk.

NAC KAZATOMPROM JSC

Yellowcake is a uranium concentrate used to make nuclear fuel.

>> *"Our uranium import dependence is a case study in how our vital domestic minerals supply chains have atrophied to levels that result in a dire national security risk."*

*–National Mining Association President and CEO Rich Nolan*

## Future is in micro

Foreseeing the transition to clean energy leaning heavily into nuclear energy, research and technology has shifted toward a solution that would not have been possible a decade ago – microreactors.

Expected to be modular, portable, and inhabit a smaller footprint than their larger nuclear counterparts, these microreactors are expected to fill in for remote operations and less-than-ideal renewable locations. While conventional reactors can produce up to 1,000 MWe and are designed to power cities, microreactors will power less than 50 MWe and could supply enough power for roughly 60,000 modern U.S. homes in places far from the grid.

While current production meets requirements now, if several hundred of these microreactors pop up around the country, the demand for uranium will spike, creating a similar issue to what the world is facing for lithium-ion battery materials such as lithium, cobalt, manganese, and graphite.

With a handful of companies predicting their pilot reactors to come online toward the end of the decade, if successful, it will begin to solve the problem of remote energy – however, if the country wants to achieve its net-zero carbon emissions by 2050 solar and wind will not be enough, the intermittent energy dependent on a sunny or windy day will never compare to continuous baseload power that nuclear can provide. DMN

ADOBE STOCK

The ash left behind from the burning of coal offers a potential domestic source of gallium, germanium, rare earths, and other minerals critical to America's clean energy and tech sectors.

# An unconventional critical minerals push

## DOE bombards the search for alternative supplies with funding

By A.J. ROAN
DATA MINE NORTH

**AS THE CRACKS IN THE WALL** continue to chill the bones of an ill-prepared American clean-energy economy, attention has been paid to nearly every facet imaginable to obtain the minerals critical to fuel a zero-carbon future; however, all has seemingly been quiet on the unconventional front.

Repeated time and time again during the ongoing transition, U.S. policymakers are becoming increasingly concerned about the overreliance on China for the minerals and metals essential to clean energy technologies.

Today, China controls roughly one-third of the global market for critical minerals and rare earth elements, and several countries, such as the U.S., Canada, Australia, United Kingdom, and many of the surrounding European Union countries, are making strides toward developing robust and domestic resource extraction and processing industries of their own to break away from the risk of a supply cutoff.

To take advantage of the federal tax credits in the U.S. for electric vehicles from legislation like the Inflation Reduction Act, American and even allied country companies based in the U.S. will require 40% of an EV battery's minerals and 50% of the components to come from the U.S. or free trade agreement (FTA) countries, recycled or raw, to be eligible for the tax credit, and for foreign companies, as long as "final assembly of which occurs within North America."

In 2027 and 2029, this requirement will increase to 80% for minerals and 100% for components.

To aid in the process, a recent executive order by President Joe Biden aims to create a domestic supply chain for critical minerals by reviewing the vulnerabilities that have persisted after the last several years of shuffling about to fill in the numerous holes in minerals and metals self-reliance.

"We can see that a lot of these existing conditions in the global market and the region support both the establishment and growth

of the rare earth metal industry, as well as the industries supporting it," said Matt Scheffel, an economist with Chmura Economics. "If we are able to target and provide economic support for a number of these industries it will allow for side-by-side growth for these industries and the rare earth metal industry to help keep job opportunities within the region."

## Cracks in the wall

With permitting practically strangling new and existing mining operations, this has severely inhibited new raw materials to help offset the resource deficit we are facing.

With construction underway for the majority of facilities to recycle and reuse existing batteries, the timeline is pushed back even further.

With most FTA countries also scrambling for their own supplies, the U.S. must fight for scraps for possibly the first time in its short history, just like everyone else.

With outdated infrastructure to be replaced in tandem with developing EVs to gum up crumbling cities that then contribute to the emissions that are heating up the planet in the first place, it seems like every which way, this is a losing battle.

However, if there is one thing America has in its favor – it is waste. And when it comes to minerals critical to a high-tech and low-carbon future, one generation's waste is the next one's treasure.

Unconventional recovery of critical minerals could be considered a sibling or cousin to recycling but unique in that it is a term used for exploring new and out-of-the-box ways to obtain the resources needed for clean energy technologies.

These can be waste residue from fossil fuel and other industries (which could fall under recycling), that include mine tailings, refuse piles, acid mine drainage, fly ash, coal waste, and wastewater produced by oil and gas supply chains.

It can include the highly controversial deep-sea mining – a feasible frontier for manganese, cobalt, nickel, and REEs – marine-derived mining for lithium, and phytomining of native plants to extract or collect minerals from the sap, leaves, and/or fruits.

Space mining—not too dissimilar to conventional mining; however, it could be considered unconventional as it would be hundreds of thousands or even millions of miles away in space and within a vacuum.

Front loader working at the open-pit Wyodak coal mine in the coal-rich Powder River Basin outside Gillette, Wyoming.

CAROL M. HIGHSMITH/LIBRARY OF CONGRESS

>> *"The key takeaway here is the Central App region has a lot of the key building blocks that are necessary for future processing facilities."*

*–Brian Hill of Crescent Resource Innovation, a financial consultant for the U.S. Department of Energy*

Even the standard method of lithium brine or claystone extraction could fall into the unconventional category, as it has broken away from the long tradition of simply digging up the earth for resources.

Distracted by the problem, there are many who have sought solutions, and the creativity and ingenuity of humans shines brightest when it comes to solving problems.

## Cleaning up

Tapping into the valuable prospect that various laws passed to fund critical minerals and metals, the Department of Energy has issued funding opportunity after funding opportunity to bolster any possible way to grow domestically produced resources.

From awards and grants to pleas for data and research, DOE has continued to push for a cleaner, greener future.

Through its Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Initiative to supporting the Earth Mapping Resources (Earth MRI) Initiative by the United States Geological Survey, the Department of Energy sees potential and has taken advantage of federal money.

This has extended to start-ups, spin-offs, small businesses, large businesses, private and public research, you name it, seeking ways with interesting and viable technologies to maximize resource development and recovery.

From a $140 million REE separation facility to a $750 million advanced energy and recycling program, then a $335 million lithium-ion recycling program to $675 million for critical materials research and commercialization, DOE has been taking advantage of the $1.2 trillion Bipartisan Infrastructure Law to rekindle industry in America, and it hopes to do so by capitalizing on clean energy.

As part of DOE, its Office of Fossil Energy and Carbon Management (FECM) has also been digging into its jurisdiction to extract resources from existing sources unconventionally.

Aiming to possibly clean up the wastewater from fossil fuel production, in February, FECM provided $17.5 million in funding for research and development projects focused on producing clean water and critical minerals from oil, gas, and coal production wastewater.

"Clean water is essential for the health and economic prosperity of our communities, but while demand from the energy sector for this vital resource has grown, aquifers in arid and semi-arid regions of the country have become depleted by drought conditions made worse by a warming climate," said Brad Crabtree, assistant secretary of DOE's Fossil Energy and Carbon Management. "By treating and reusing the

large volumes of wastewater produced through fossil fuel production and use, these projects will help to make wastewater safe for the environment and a valuable resource for the American public, especially for water-stressed communities."

Furthermore, DOE announced $5.3 million in grants in December 2022 for five cutting-edge projects intended to advance research supporting the domestic production of rare earth elements and other critical minerals.

Under the purview of FECM, the agency tasked the National Energy Technology Laboratory to oversee the projects.

The projects would initially leverage the unique expertise of five DOE national labs to develop technologies that improve sensing and characterization of unconventional and secondary sources that contain rare earth elements and other critical minerals.

The selected national labs included:

• Lawrence Berkeley National Laboratory received $1.2 million to develop a machine learning tool to identify hot zones for rare earths and critical minerals in mine tailings, particularly on coal and sulfide tailings.

• Los Alamos National Laboratory received $1.2 million to work with partners at the Wyodak coal mine in Wyoming to develop a machine learning tool for mine-scale assessment of rare earths and critical minerals.

• Pacific Northwest National Laboratory received $1.2 million to develop a drone-based real-time artificial intelligence analysis survey technology to determine the quantity of critical minerals in coal, coal-related and energy-related waste streams.

• Sandia National Laboratories received $1.2 million to assess the extractability of critical minerals, including rare earths, from major oil and gas shale formations across the US. Specifically, in-situ extractability of these metals using its newly developed extraction system.

• SLAC National Accelerator Laboratory received $500,000 to characterize critical minerals from energy production waste streams, from initial exploratory drill samples to final waste material after extraction.

With dozens of engagements to find critical minerals, metals, rare earths, from every possible source, it isn't that nothing is happening—news is just overshadowed by the arms race of EVs, so unconventional has fallen by the wayside.

## Coal renewed

There is an almost subconscious belief that coal's role in American energy is finished – this couldn't be further from the truth. If for no other reason than coal deposits often have trace amounts of gallium, germanium, rare earths, and other minerals critical to the U.S.

While the concentrations of these high-tech metals are typically too low for economic recovery, burning the coal transforms trace quantities into potential ore – and more than a century of burning coal to generate affordable power has produced an estimated 2 billion tons of coal ash at various sites across the country.

"Coal ash is rich in rare earth elements, as rich as some of the ore deposits," said Linda Wang, a professor of chemical engineering at Purdue University. "The United States produces about 129 million tons of coal ash every year."

While this annual production of ash is expected to wane as America transitions to lower-carbon energy sources, over 100 years of coal-fired electrical generation has created billions of tons of this REE-enriched waste product – and if technologies that can maximize the economic value of extraction are developed, not only would it provide these desperate materials, but it would also clean up these waste sites.

ADOBE STOCK

**Coal seams, ash, and other materials were studied across Central Appalachia to determine critical mineral availability. Taking advantage of preexisting coal mining infrastructure would give the industry a leg up in extracting and processing clean energy metals.**

Speckled all throughout the decades of coal mining along the Appalachian Mountains, "coal country," which has long dwindled into a shell of its former self, may see renewed life and industry as technologies develop that turn heaping black hills into recovery-ready stock.

After almost two years of study, researchers have presented optimistic results on Central Appalachia's potential to develop industries around the extraction and processing of rare earth elements and other critical minerals.

Covering a region that includes parts of Virginia, West Virginia, Tennessee, and Kentucky, where critical minerals and rare earths have been identified in the coal, as well as underlying rock, researchers from the Evolve Central Appalachia (Evolve APP) project funded by DOE has been working since 2021 to determine the historically coal-dependent area's potential.

Researchers ultimately found 10 coal seams in Southwest Virginia with significant amounts of critical minerals, with concentrations ranging widely from 8.4 to 165.7 parts per million. Comparatively, the highest concentrations of critical minerals in seams throughout Kentucky, Tennessee and West Virginia reached 250 ppm.

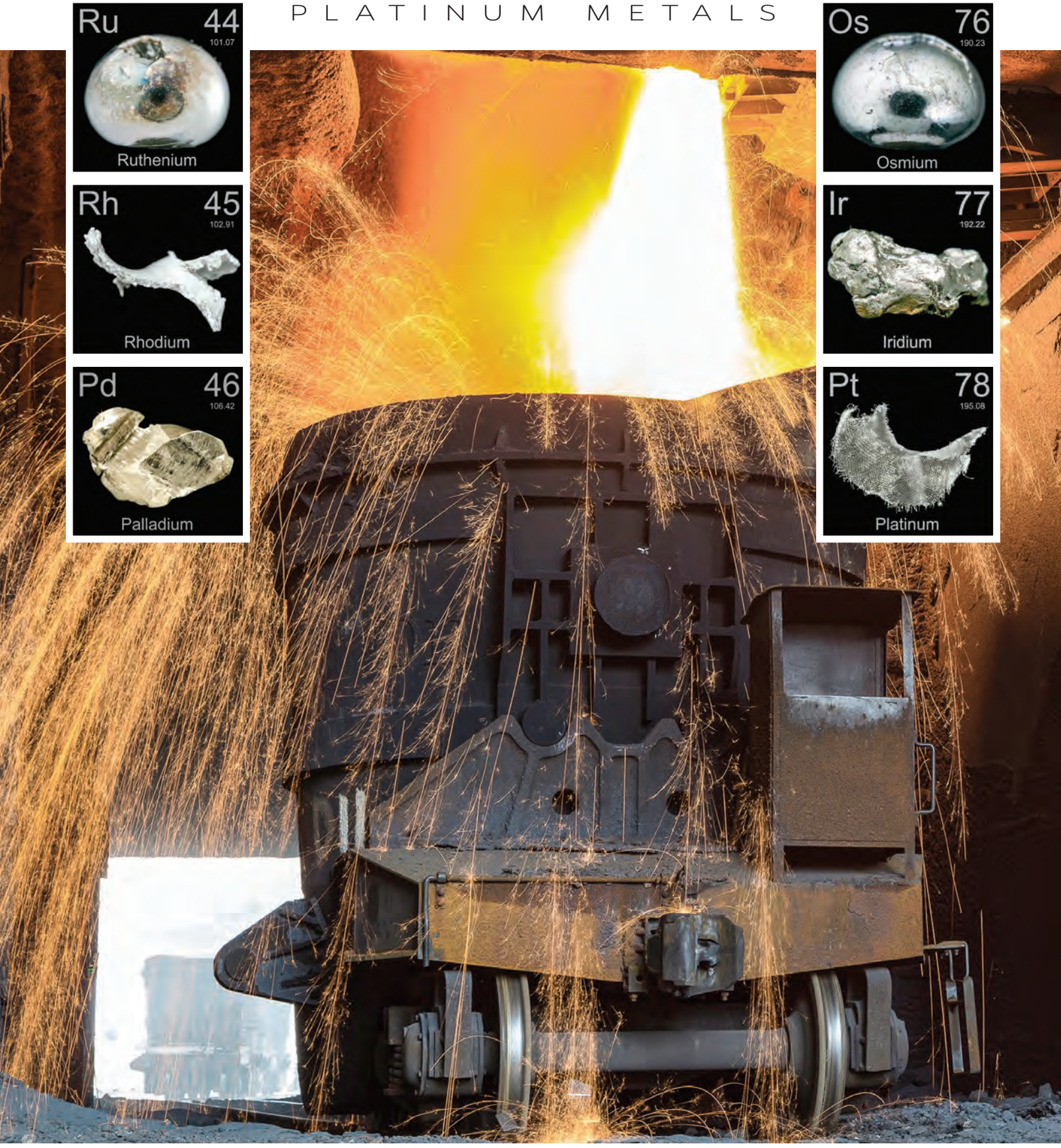
Danny Gray of Gray Energy Technologies found that coal ash in the region had an average concentration of critical minerals and rare earth elements that were 500 parts per million.

"We know that you got to handle more than 2,000 tons in order to get more than 1 ton," Gray said. "That presents material handling challenges."

Due to the region's coal mining history, most of the technology, transportation and other infrastructure needed for the extraction and processing of these resources is already in place but will, at the very least, require mine operators to learn a few new skills.

"The key takeaway here is the Central App region has a lot of the key building blocks that are necessary for future processing facilities," said Brian Hill of Crescent Resource Innovation, a financial consultant for the U.S. Department of Energy.

The challenge for workers accustomed to coal mine extraction processes will be learning how to handle multiple new materials, but if the prospect of a good-paying job is on the table, next to reigniting industry in their hometown, it can be reasonably assumed they'd make the effort. DMN




**The production of green hydrogen to decarbonize steelmaking and other industrial processes, which account for 23% of the United States' greenhouse gas emissions, is expected to be a driver for platinum group metal demand in the coming years.**

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# Platinum metals are catalysts for change

## PGMs find new planet-saving role for clean energy transition

By SHANE LASLEY
DATA MINE NORTH

ANGLO AMERICAN

A large hydrogen-fueled mining truck developed for one of Anglo American's platinum group metal mines in South Africa.

**AFTER 50 YEARS OF SCRUBBING** the emissions from fossil-fueled transportation and industry, platinum group metals are finding new roles as catalysts for the transition to a low-carbon energy future.

"Platinum group metals (PGM) are critical for today's energy sector industrial base and will play a key role in tomorrow's decarbonized economy," U.S. Department of Energy inked in an informational brochure on these transitional metals, also known as platinum group elements.

PGMs – platinum, palladium, rhodium, ruthenium, iridium, and osmium – have a long list of attributes that make them indispensable to global industries. These characteristics include exceptionally high resistance to wear, tarnishing, and chemical attack; the ability to endure high temperatures; and excellent electrical stability. It is the catalytic properties of this group of metals, however, that scrubbed the exhausts from fossil-fueled energy of the 20th century and are being used to create cleaner fuels for the low-carbon energy future that lies ahead.

"Catalysts based on PGMs are used in a variety of applications such as chemical manufacturing, automotive catalytic converters, and petroleum refining," DOE wrote. "They are also central to emerging decarbonization technologies such as water electrolyzers for green hydrogen production and fuel cells for vehicles and stationary energy storage."

While the blue-collar job of scrubbing harmful emissions from automobile tailpipes and industrial smokestacks has been the primary use for PGMs, these metals are just as comfortable in a lab coat or at a black-tie event.

"PGMs are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment," the U.S. Geological Survey penned in its Mineral Commodity Summaries 2023 report.

Three PGMs in particular – platinum, palladium, and rhodium – are minted into coins and bars for investment purposes, solidifying the group's role as precious metals.

The rarity and beauty of jewelry donned at a black-tie soiree, combined with hardworking durability and catalytic characteristics featured on Mike Rowe's "Dirty Jobs," elevates the criticality of this group of elements.

### A catalyst for change

As fossil fuel-burning cars give way to electric mobility, so goes the need for catalytic converters. The same catalytic properties used to scrub the exhaust from ICE vehicles, however, are being used to convert water into green hydrogen fuel.

DOE is particularly interested in the production of green hydrogen to decarbonize steelmaking and other industrial processes in the U.S., which account for 23% of the nation's greenhouse gas emissions.

"To meet the nation's goal of net-zero carbon emissions by 2050, decarbonization of these energy and emissions intensive processes will be crucial. PGM catalysts, and the green hydrogen produced with them, can enable dramatic emissions reductions in these hard-to-decarbonize industrial sectors," the Energy Department wrote.

Fuel cells being manufactured for large trucks, busses, trains, ships, and even airplanes also take advantage of the PGM's catalytic properties to split hydrogen molecules into electrons that create a flow of electricity and protons that unite with oxygen to produce water vapor exhaust and heat.

The platinum metals, however, are very rare and roughly 98% of the world's known reserves are found in South Africa (90%) and Russia (8%).

"The six PGMs are among the least abundant elements on earth and occur in only a few countries worldwide, with the majority of production and reserves in South Africa and Russia," DOE wrote. "To secure the supply chains for these clean energy technologies, as well as green hydrogen and chemical manufacturing, the

United States needs to invest in its domestic resources and in innovations in PGM substitutions, material efficiency, and recycling."

## Five critical platinum metals

The combination of scarcity, import reliance, and importance to clean energy and other industrial sectors plants PGMs on critical minerals lists compiled by both USGS and DOE.

After considering the entire suite of PGMs as one commodity on its original 2019 critical minerals list, USGS evaluated each of these metals separately when updating the list in 2022.

The 2022 list names five PGMs – iridium, platinum, palladium, rhodium, and ruthenium – as critical to the U.S.

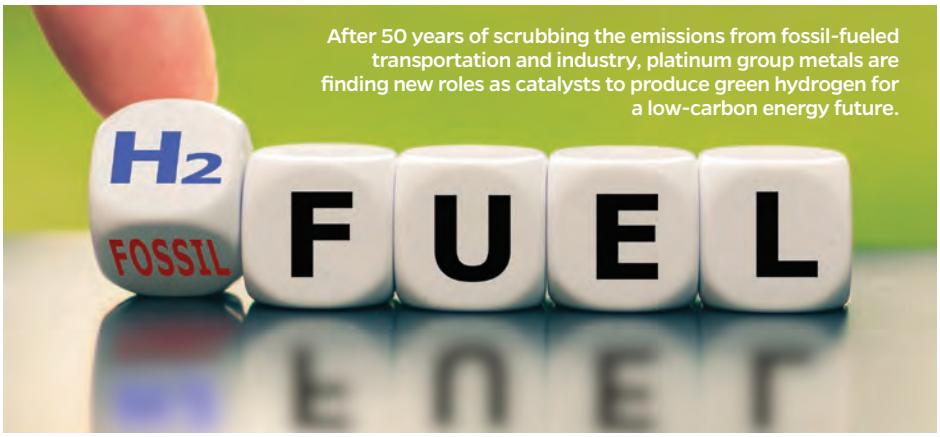
**IRIDIUM** – The rarest of the PGMs, iridium sells for more than $4,500/oz. This most expensive PGM is known for its chemical and thermal stability. Iridium is the anode catalyst for hydrogen production. Like rhodium, iridium is also used as a hardening agent for platinum. This biologically compatible PGM also has medical applications.

**PALLADIUM** – With the unique ability to absorb hydrogen, palladium is used in chemical processes that require hydrogen exchange, such as those used to produce raw materials for synthetic rubber and nylon. Palladium also has excellent catalytic properties and is often used as a substitute for platinum but, at roughly $1,300/oz, is more expensive.

**PLATINUM** – This PGM namesake, prized as a precious and industrial metal, sells for around $900 per ounce. In addition to its primary use as a catalyst for scrubbing emissions and hydrogen fuel technologies, platinum is used for computer hard drives, fiber optics, LCDs, spark plugs, pacemakers, and dental fillings.

**RHODIUM** – Rhodium is a silver–colored metal that is extremely resistant to corrosion and highly reflective – qualities used to add luster to jewelry, mirrors, and searchlights. Rhodium is also used to harden and improve the corrosion resistance of platinum and palladium alloys. Due to its uses and rarity, rhodium sells for more than $3,000/oz.

**RUTHENIUM** – Ruthenium is very hard and also a good alloying agent for platinum and palladium. Due to its conductive properties and durability, this PGM is used in wear-resistant electrical contacts for computers and smartphones. Ruthenium, which is also used in highly efficient solar cells and as a catalyst, sells for under $500/oz.



After 50 years of scrubbing the emissions from fossil-fueled transportation and industry, platinum group metals are finding new roles as catalysts to produce green hydrogen for a low-carbon energy future.

ADOBE STOCK

## Critical iridium and platinum

Based on its analysis of forward-leaning energy technologies, DOE has included two PGMs – iridium and platinum – on its list of critical materials.

Due to its importance to the energy transition and high supply risks, iridium ranks particularly high on the U.S. Energy Department's list of critical materials.

This is largely due to iridium being the catalyst of choice for the anodes of the proton electrolyte membrane (PEM) electrolyzers that produce green hydrogen from water. This extremely scarce PGM's ability to endure the acidic conditions that occur during this process makes the catalyst worth its weight in iridium.

"Iridium is one of the rarest elements in the earth's crust," DOE wrote. "A particular challenge to the supply of iridium in coming years is the expected decline in demand for co-products palladium and rhodium used in internal combustion vehicles' catalytic converters and palladium used in diesel engine vehicles' catalytic converters. The majority of iridium is produced from mines and refiners in South Africa and Zimbabwe where mine operations have been affected by environmental, operational, safety, and labor issues."

Despite the high price of iridium, it is almost never found in concentrations that would support its recovery independent of the other platinum metals.

"It is unlikely that iridium would be produced as a primary product, although some iridium may be recovered from platinum mine overburden, discarded ores, and tailings," DOE penned in its 2023 Critical Materials Assessment published in July.

While the Stillwater and East Boulder mines, about 85 miles southwest of Billings, Montana, produced roughly $880 million of PGMs during 2022, iridium is not among the platinum metals recovered. This makes the U.S. 100% dependent on imports for this critical rare metal.

For these reasons, iridium is high on the Energy Department's list of materials critical to America's low-carbon emissions future.

While the criticality of platinum is not as high as iridium, DOE considers the namesake PGM as near-critical in the short term and rising into the critical category during the 2025-2035 medium span considered in the Critical Materials Assessment.

"Platinum demand for catalytic converters is expected to decline after 2025 as vehicle technologies transition to battery and fuel cell-powered vehicles (FCEVs)," DOE penned in the report. "This decline may be mitigated as PEM fuel cells and electrolyzers are adopted as important technologies for the hydrogen economy."

In the short term, the Energy Department foresees an excess supply of platinum as the auto sector will need less for catalytic converters as it phases out ICE vehicles in favor of EVs. The rise in hydrogen fuel technologies and fuel cell-powered transportation is expected to create new demand that outpaces supply in the medium term considered in DOE's Critical Minerals Assessment.

"The supply risk for platinum is significant in the short and long term," DOE wrote.

During 2022, the U.S. was dependent on imports for 66% of its platinum needs.

## North American platinum metals

Both Canada, the fourth largest producer of PGMs, and the U.S., the fifth largest, have highly prospective areas for bolstering the production of this group of critical catalyst metals.

Canadian mines produced 699,000 troy ounces of PGMs in 2021.

Roughly 73% of Canada's platinum metals are mined in Ontario, which is home to Impala Canada's Lac des Iles Mine, the only primary PGM mine in the country. The balance of the Ontario PGMs is produced as a byproduct of nickel mining in the Sudbury region, where global miner Vale has five mines, a mill, and a smelter.

There are two advanced exploration projects in northern Ontario that are focused on PGMs as the primary commodities.

When it comes to the clean energy transition, it is fortuitous that PGMs are found alongside the nickel needed for EV and renewable energy storage batteries, and the Canadian PGMs not produced in Ontario are recovered as a byproduct of mining the battery metals in Quebec, Manitoba, Newfoundland and Labrador.

Besides the PGM-rich regions of Montana and Ontario, along with the platinum metals being produced as byproducts of nickel mining in Canada, there are some areas of North America prospective for future sources of this group of high-priced critical metals.

A special category of PGM-hosting deposits that partially derive their name from Alaska – Ural-Alaska-type ultramafic complexes – hint at the prospectivity for this group of industrious precious metals across the Last Frontier.

Wrangellia – a geological terrane that arcs more than 1,250 miles across the breadth of Alaska, through southern Yukon, and down the western side of British Columbia – is highly prospective for these ultramafic deposits enriched with nickel, copper, cobalt, platinum, palladium, iridium, rhodium, osmium, ruthenium, gold, and silver.

The most advanced PGM deposit along this massive geological terrane is Nickel Shäw in southeastern Yukon, about 60 miles east of the Alaska border.

According to a 2018 calculation, Nickel Shäw hosts 323.4 million metric tons of measured and indicated resources averaging 0.26 g/t (2.65 million oz) palladium, 0.2 g/t (2.63 million oz) platinum, 0.27% (1.88 billion lb) nickel, 0.16% (1.11 billion lb) copper, and 0.015% (107 million lb) cobalt.

Nickel Creek Platinum Corp. is exploring 11 high-priority targets that could add to this resource as it continues to optimize plans for developing a mine at Nickel Shäw.

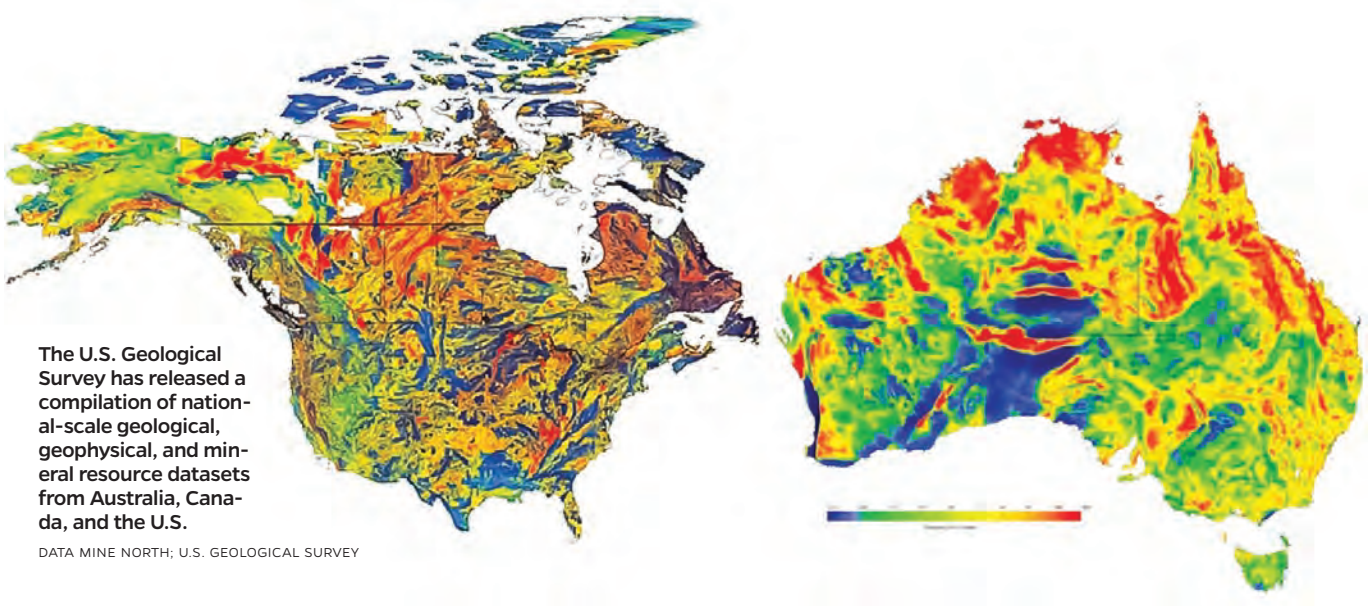
There are intriguing signs that similar PGM-nickel-copper-cobalt deposits may be found in the Alaska portion of Wrangellia, such as the Nikolai property about 250 miles northwest of Nickel Shäw.

Discovered by INCO in the 1990s, the Nikolai project hosts a roughly 10-mile-long trend of lower-grade nickel-copper-cobalt-chromium-PGE mineralization.

Alaska Energy Metals Corp., which recently acquired this property, is carrying out drilling in 2023 to establish a resource at this bulk tonnage target known as Eureka and is exploring much higher-grade targets on the adjacent Canwell property.

One particularly high-grade rock collected from this Alaska property contained 13.6% nickel, 2.9% copper, and 26 g/t PGMs.

"Located in the USA, we intend to help North America transition to electrical power for vehicles and other rechargeable battery powered products," said Alaska Energy Metals President and CEO Gregory Beischer. DMN



The U.S. Geological Survey has released a compilation of national-scale geological, geophysical, and mineral resource datasets from Australia, Canada, and the U.S.

DATA MINE NORTH; U.S. GEOLOGICAL SURVEY

# Australia, Canada, and US merge geo data

## Compile national-scale datasets to assist tri-national critical minerals mapping initiative

By SHANE LASLEY

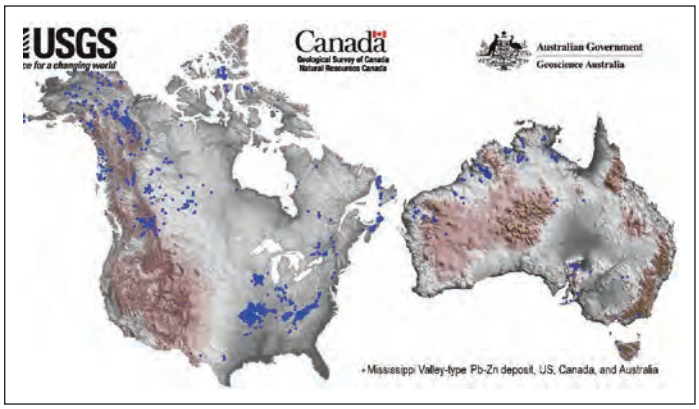
DATA MINE NORTH

**PART OF A LARGER COLLABORATION** to better understand the critical minerals potential across Australia, Canada, and the United States, the federal geological surveys from the three countries have merged national-scale geological, geophysical, and mineral resource information into a single dataset that is expected to enhance critical mineral discovery.

"Geology doesn't stop at the border and neither does our data," said U.S Geological Survey scientist Anne McCafferty, who led the data compilation effort. "Scientists will now be able to look at geological and geophysical data seamlessly across both Canada and the United States, as well as make direct comparisons to Australia."

The tri-national geologic, geophysics, and mineral resource data release includes more than 40 earth science data layers, including a new map of variations in the Earth's natural magnetic field for the entirety of Canada and the U.S that geoscientists can use to develop three-dimensional representations of geology underground.

These standardised datasets, spanning the continents of Australia and North America, enable unique investigations into the controls on critical mineral distribution which were simply not possible beforehand," said Geoscience Australia scientist Karol Czarnota. "I'm sure they will be a foundation for ongoing research and innovation for many years to come."




A team led by the Geological Survey of Canada used Critical Minerals Mapping Initiative geophysics datasets and machine-learning techniques to map Mississippi Valley-style zinc deposits in Australia and North America.

### Critical Minerals Mapping Initiative

The tri-national geo-data release is part of the Critical Minerals Mapping Initiative, a partnership forged in 2019 to support the

*>> One way the combined geological information has already been leveraged is as a much larger and more diverse dataset for artificial intelligence and machine learning mineral exploration techniques.*

establishment of a diversified supply of critical minerals in Australia, Canada, and the U.S.

"This joint data release speaks to our continued commitment to improve scientific cooperation and data sharing between the U.S. Geological Survey, Geoscience Australia, and the Geological Survey of Canada," said Geological Survey of Canada scientist Christopher Lawley.

America's heavy dependence on countries like China for critical minerals and an overall lack of knowledge about many of these elements needed for clean energy, high-tech devices, and military hardware was a primary driver behind the formation of CMMI.

In addition to data-sharing, CMMI combines the expertise brought to the table by each of the nation's geological teams.

"Because each country has expertise in different fields, bringing all of these experts together can create a strong foundation of mineral information that can be used by policy makers, resource-managers, industry and others to help meet the needs of all three countries' economies and security," USGS penned in a 2020 announcement of the critical minerals collaboration.

This geological partnership will also help Australia, Canada, and the U.S. coordinate supply chains for the minerals critical to the clean energy goals and manufacturing sectors in all three countries.

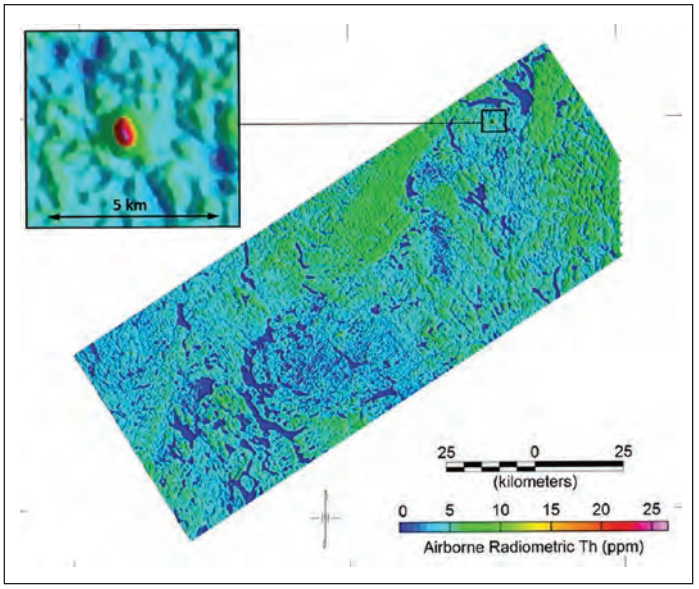
One way the combined geological information has already been leveraged is as a much larger and more diverse dataset for artificial intelligence and machine learning mineral exploration techniques.

A CMMI team led by the Geological Survey of Canada has already used the data layers to map the potential for certain types of zinc deposits in all three nations.

The sediment-hosted zinc deposits this investigation focused on often host gallium and germanium, a pair of technology metals important to chipmaking that have gained attention due to China's dominance in their supply and restrictions on exports.

The international team of geoscientists is using similar techniques to model the potential for other critical mineral systems across Australia, Canada, and the U.S. DMN

U.S. GEOLOGICAL SURVEY




**A geophysical anomaly identified during a USGS Earth MRI scan in northern Maine led to what appears to be a significant rare earths-niobium-zirconium discovery on Pennington Mountain.**

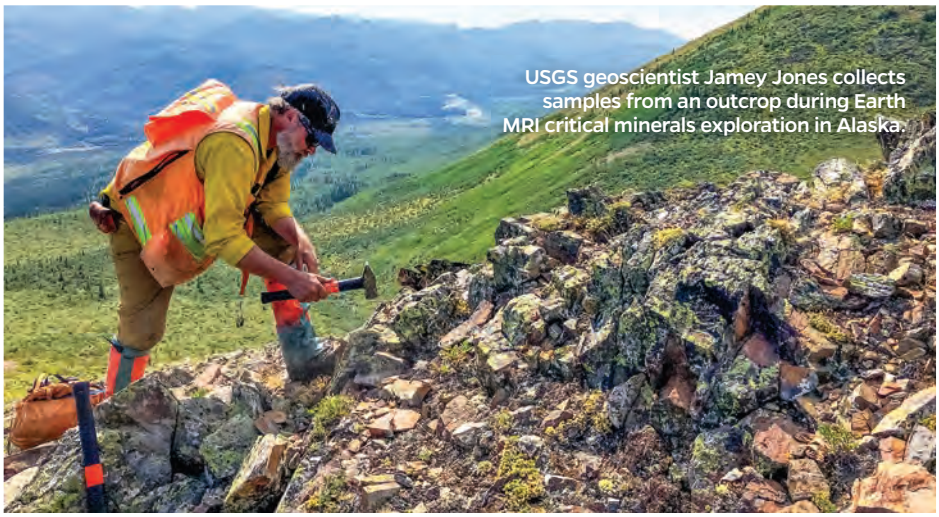
CHUNZENG WANG, UNIVERSITY OF MAINE-PRESQUE ISLE

**A fine-grained volcanic rock with rare earths, niobium, and zirconium discovered in Pennington Mounatian, Maine, as a result of a geophysical survey carried out under the USGS Earth Mapping Resources Initiative.**

# Earth MRI scan for US critical minerals

## USGS is partnering with state geologists in nationwide search

By SHANE LASLEY
DATA MINE NORTH



USGS geoscientist Jamey Jones collects samples from an outcrop during Earth MRI critical minerals exploration in Alaska.

ADRIAN BENDER, U.S. GEOLOGICAL SURVEY

**FROM RARE EARTHS IN NORTHERN** Maine to lithium in Southern California and graphite in Alaska, the U.S. Geological Survey is on a mission to discover minerals critical to the nation's economy and clean energy goals on American soil. Or, more accurately, under American soil.

This nationwide endeavor is officially called the Earth Mapping Resources Initiative, but is better known as Earth MRI, a clever moniker that reflects the earth penetrating scans that are providing geoscientists with a glimpse of the rocks hidden below the surface.

Carried out in partnership with the Association of American State Geologists, Earth MRI is providing a much more detailed understanding of America's geology and mineral resource potential through new mapping, geophysics, and geochemical sampling.

What makes the name so clever is the subsurface imaging reminiscent of a medical MRI. Much like doctors use magnetic resonance imaging to help diagnose and pinpoint exactly what is going on inside a body, geoscientists can use the Earth MRI data to see what is below the surface without the need for probes or exploratory surgery.

These subsurface images are produced with geophysics, which utilizes a cadre of sensing techniques and equipment to identify various rock characteristics that provide a picture of the geology below the surface.

Two geophysics techniques, airborne magnetic and radiometric geophysical surveys, are particularly well-suited for the initial critical minerals assessment USGS has set out to achieve with its Earth MRI scans.

The magnetic surveys allow geoscientists to "see through" nonmagnetic rocks and cover such as vegetation, soil, and water to identify magnetic anomalies that reveal geological features and potential accumulations of metals within the Earth.

The radiometric surveys identify natural low-level radiation potassium, uranium and thorium in rocks and soil, which provides clues to the type of mineralization that lies below.

Geoscientists are using the data from these surveys to help identify the best locations to search for critical minerals.

"The airborne geophysical surveys help pinpoint the areas where follow-up geologic mapping efforts will provide the most value," said Eric Anderson, a USGS research scientist, explained during a $1.9 million Earth MRI survey of Montana announced in July.

While Earth MRI was launched as part of a 2019 strategy to ensure a reliable domestic supply of critical minerals, this program expanded into a truly nationwide program with the passage of the Bipartisan Infrastructure Law and $320 million to fund the program for five years.

"These historic investments will modernize our mapping of the United States," said Sarah Ryker, USGS associate director for energy and mineral resources.

### Federal resources, local knowledge

The USGS partnership with state geologists plays a vital role in determining the best places in the nation to look for the 50 minerals and metals critical to the U.S.

"Merging federal resources with local knowledge of the state surveys creates an efficient and thorough venue to quickly further national understanding of the distribution of our resources," said Erin Campbell, president of the Association of American State Geologists.

Funneling some of the Earth MRI money down to the state level also equates to more rock hammer-toting geologists mapping and sampling the most prospective regions of each state, while the USGS has helicopters and planes equipped with earth-sensing geophysical equipment flying overhead.

Programs to be carried out under the funding include:

**National Cooperative Geologic Mapping Program:** New maps created by state geological surveys under this program are helping to refine the understanding of the geologic framework of mineral areas of

interest. In addition to identifying mineral potential, these maps support decisions about the use of land, water, energy, and minerals, as well as the potential impacts of geologic hazards such as earthquakes, landslides, and volcanoes on communities.

**National Geological and Geophysical Data Preservation Program:** Earth MRI is partnering with state agencies to support the preservation of physical geological samples that would be costly or difficult to replace. Preserving and cataloging these samples of drill core, rock, and soil is creating rock libraries that can be referenced when geologists have new ideas or are looking for minerals that are critical to future technologies that had little or no use in the past.

**USGS 3D Elevation Program (3DEP):** This program utilizes private sector contractors to fill data gaps in the nation's topographic mapping in areas with potential for critical mineral resources. Lidar, a laser-based scanning of terrain to create high-resolution digital elevation models, is being used to assist in the development of more accurate maps of surface geology, which geoscientists can use to extrapolate the extent of the rock formations at depth. Lidar data can also help define the location and volume of mine waste materials exposed on the land surface.

**Mineral Resources Program:** Federal and state geologists are carrying out geochemical reconnaissance surveys over underexplored geologic settings, which provides initial data for planning and prioritizing future programs. This sampling of the soil and rocks exposed at surface is helping the USGS determine where to have private contractors fly airborne geophysical surveys based on the critical mineral potential seen on the surface.

The U.S. Department of Interior, which oversees USGS, says mapping of both unmined geology and the tailings left from previous mining, will help ensure minerals critical to the energy transition can be mined domestically and with strong environmental, social, and governance (ESG) standards.

So far, USGS has completed or is planning to carry out Earth MRI programs in over 39 states and Puerto Rico.

## The Maine eureka moment

While the majority of the Earth MRI scans are being carried out over Western U.S. states and Alaska, which are particularly mineral-rich areas of the country, one of the initiative's most exciting early critical minerals discoveries was made in Maine.

An initial look at the geophysical maps generated from an Earth MRI scan carried out in northern Maine was a eureka moment for USGS geophysicist Anji Shah.

"As we were examining the data, all of a sudden, this feature caught my eye. I knew immediately we had something special here," recalled Shah.

This eye-catching feature was a nearly half-mile-wide bright red radiometric hot spot on a map of cooler greens and blues – a geophysical signature similar to other areas where deposits of rare earths and associated critical minerals had been discovered.

"This is really exciting scientifically," she said.

The USGS informed Maine geologists of the exciting geophysical fingerprint of a significant rare earth discovery.

Chunzeng Wang, professor of earth and environmental sciences at the University of Maine at Presque Isle, was as excited as Shah about the discovery and wasted no time trekking 40 miles northwest to Pennington Mountain, where the Earth MRI anomaly was identified.

NASA

NASA's Arvis, a jet with hyperspectral equipment, flies over snowy mountains.

"It's a perfect example of the science working just as intended and the importance of scientific collaboration," said Amber Whittaker, senior geologist at the Maine Geological Survey. "Having all of us involved meant as soon as we identified the feature, Professor Wang was onsite within a day to do the recon work."

Lab work showed the rocks collected from the Earth MRI anomaly by Wang and his colleagues did indeed contain rare earths, which are in high demand due to their use in electric vehicle motors and a plethora of high-tech devices. The samples also contained niobium and zirconium, critical metals used in high-strength steels, ceramics, and superalloys.

"I was astonished when seeing the analytical results that the rocks were so significantly enriched in rare earth elements and several trace metals," the professor said.

Wang and his colleagues discovered that the critical minerals at Pennington Mountain are hosted in trachyte, a type of volcanic rock known to host similar rare earth-niobium-zirconium mineralization in Australia and China.

"This discovery shows the importance of new evaluations for potential critical mineral resources based on integrated studies involving geophysics, geology, and geochemistry," said John Slack, USGS scientist emeritus from Maine who coauthored a scientific paper on the discovery with Wang.

Given what they learned so far, USGS and Maine geologists believe other rare earth-enriched deposits may exist in northern Maine.

"It shows how much there is still to discover about Maine's geology," said Whittaker.

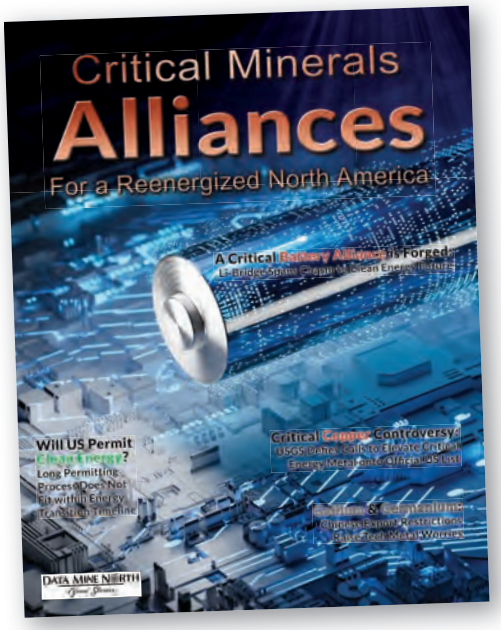
## Last Frontier for critical minerals

While the Maine discovery stands out due to the strength of the rare earth indicating geophysical anomaly in an area not well known for its critical mineral potential, the bulk of the Earth MRI scans are being carried out across the American West and Alaska.

Home to deposits and prospects enriched with 49 out of the 50 minerals deemed critical to the U.S., Alaska is considered by many as the single best place to explore for this suite of high-tech and clean energy metals.

"The Last Frontier remains a frontier for critical mineral resource development," U.S. Geological Survey Director David Applegate said during a 2022 critical minerals summit in Alaska.

Over the past two years, the USGS has allotted more than $12.5 million of Earth MRI funds to better understand the critical minerals potential across America's Last Frontier.

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U.S. GEOLOGICAL SURVEY

University of Maine geologists hike through the forest at Pennington Mountain.

This includes a $6.75 million program in 2022 to explore the Yukon-Tanana Upland, a roughly 100- by 300-mile Alaska's Interior region where the city of Fairbanks is located, and a $5.8 million program this year to scan the more remote Kuskokwim Mineral Belt, which extends the 100-mile-wide critical minerals belt another 600 miles to the southwest.

While both of these regions that form a 900-mile belt across the breadth of the Last Frontier State are highly acclaimed for their gold potential, they also happen to be enriched with at least 30 of the minerals critical to the U.S.

"From the Yukon-Tanana region in the east to the Kuskokwim River in the west, we are working with the entire state of Alaska to assess domestic resource potential and secure a reliable and sustainable supply of critical minerals," said Department of the Interior Assistant Secretary for Water and Science Tanya Trujillo.

Alaska Division of Geological & Geophysical Surveys Director David LePain said, "The State of Alaska and industry exploration geologists are already greatly benefiting from the enhanced understanding of Alaska's geology and mineral-resource potential provided by the new Earth MRI geoscience data."

### Scanning the American West

Much like America's Last Frontier, the "Lower 48" states west of the Rockies are abundantly enriched with critical minerals, and the USGS is investing heavily into Earth MRI scans to better quantify this potential.

Earth MRI scans over America's West include:

- More than 90% of Nevada, which is considered the most lithium-rich state in the nation and highly prospective for most of the other critical minerals.
- The majority of Idaho, including an area along the border with Montana, that hosts high-grade deposits of the rare earth element niobium.
- The southern half of Arizona, an area highly prospective for at least 15 critical minerals, including aluminum, cobalt, lithium, and manganese.
- Swaths of Wyoming prospective for more than 40 critical minerals, including indium, gallium, germanium, and rare earths.
- Areas of southwestern Montana with the potential for at least 25 critical minerals, including antimony, cobalt, and tin.
- A stretch of western Utah enriched with nearly 20 critical minerals that include bismuth, indium, and platinum group metals.
- Parts of northern, central, and southwestern Colorado with critical minerals such as tellurium, vanadium, and tantalum.
- The southwest corner of New Mexico prospective for aluminum, antimony, rhenium, scandium, and 24 other critical minerals.
- A small southeastern Oregon region that hosts the northern half of the McDermitt Caldera, which hosts some of the richest lithium deposits in the U.S.
- A swath of northeastern Washington prospective for rare earths, tin, and critical minerals associated with copper mineralization.

"Through these investments, the U.S. Geological Survey is making critical scientific advancements in data mapping and preservation that will equip future generations," said Trujillo. DMN


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