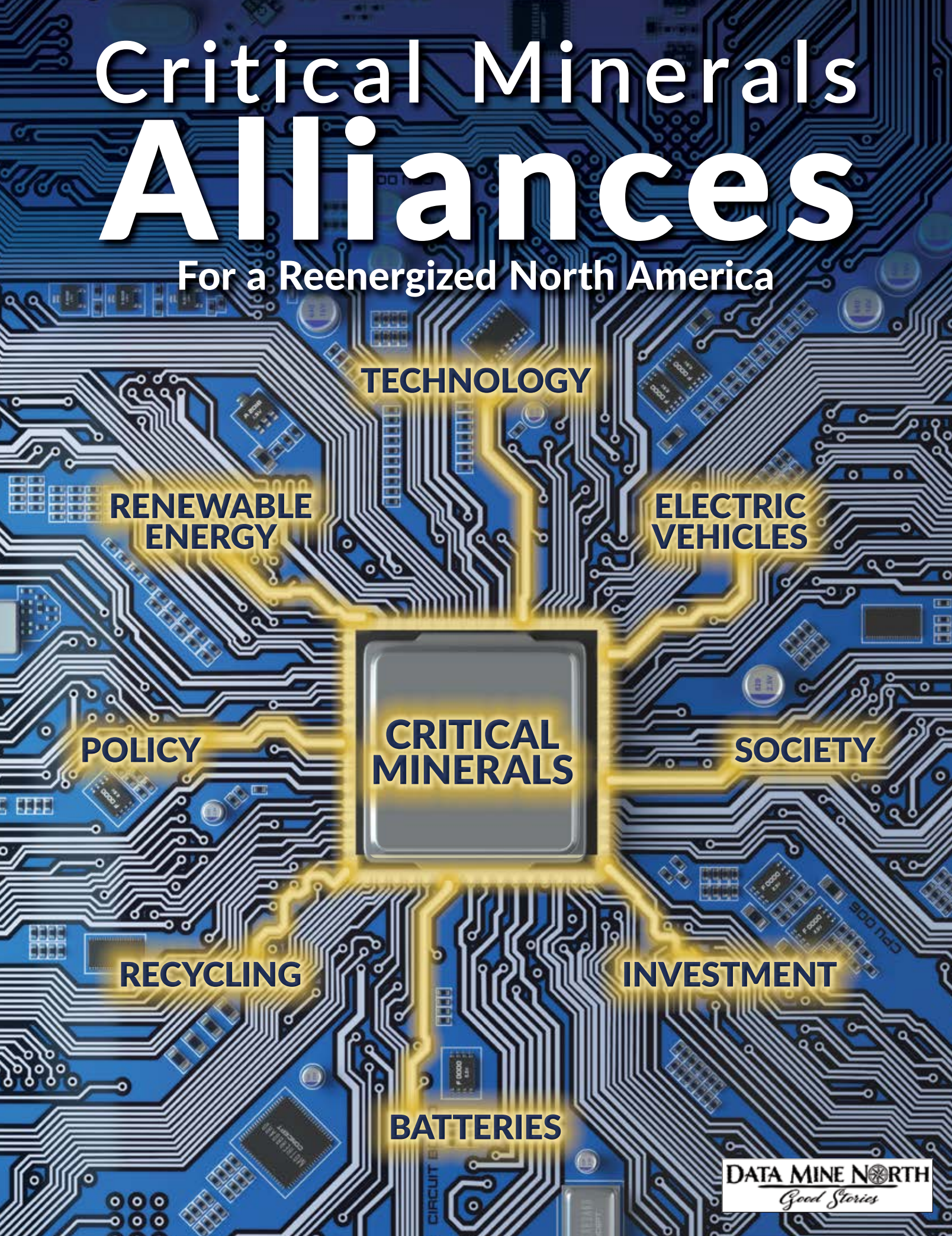
Critical Minerals Alliances

For a Reenergized North America



DATA MINE NORTH
Good Stories

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Critical Minerals Alliances
Released September 12, 2022

Critical Minerals Alliances is a special magazine published by Data Mine North. To order additional copies of this special publication, contact Laura Ross at laura@miningnewsnorth.com.

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ABOUT THE COVER:
Graphic Design of the cover of Critical Minerals Alliances 2022 was provided by Chris Day of Lions Light Corp.; photo licensed from Adobe Stock.

Printed by Century Publishing, Post Falls, Idaho

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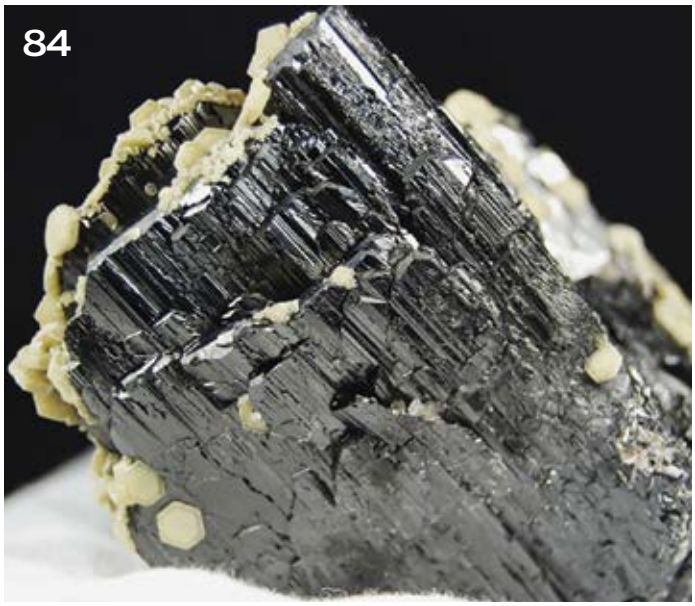



The decisions we make on how to supply, use, and recycle the minerals and metals that are the basic building blocks of the Renewable Energy Revolution will shape the world we leave for posterity.

ADOBE STOCK

Unlikely Critical Minerals Alliances 2022

Coming together to build the clean energy future

By SHANE LASLEY
DATA MINE NORTH


SHANE LASLEY

THE SHIFT AWAY FROM THE FOSSIL FUELS that powered the Industrial Revolution and transported humankind through the 20th century and toward the clean energy technologies that will propel us into the future has the world at an inflection point – the decisions we make on how to supply, use, and recycle the minerals and metals that are the basic building blocks of the Renewable Energy Revolution will shape the world we leave for posterity.

The optimum solution to laying the foundation for the next epoch of human progress will only be discovered through the forging of unlikely alliances between the woke and old school, environmental conservationists and natural resource developers, liberals and conservatives, national laboratories and private sector entrepreneurs, local stakeholders and global mining companies, venture capitalists and innovators, and everyone else with visions of a cleaner, greener, and high-tech future.

As a journalist that has spent 15 years covering the minerals sector, I have witnessed strong passions for and against mining. Both have their merits – every aspect of the human experience relies on minerals dug up from the earth; yet mining is a destructive endeavor with a bygone legacy of not rehabilitating the scars of digging up the elements of innovation.

Minerals and metals dug up from the earth, however, are the very foundation upon which the clean energy future will be built.

The World Bank Group estimates that more than 3 billion tons of minerals and metals will be required to build the EVs and renewable energy infrastructure needed to achieve the climate goals outlined in the Paris Agreement – the more ambitious targets set by global leaders during the 2021 U.N. Climate Change Conference will require even more mining, sooner.

While recycling will eventually offer a substantial supply of the minerals and metals needed to continue building a (hopefully) brighter future, it will take an enormous amount of new mining to

provide enough battery materials, rare earth elements, copper, and other minerals and metals critical to the Energy Transition. This is above and beyond the exciting advances in cutting-edge technologies that are being made possible by material scientists discovering new ways to leverage the unique properties of previously obscure elements – creating new demands for minerals and metals that previously had few uses.

Should mining for the materials critical to our clean energy and high-tech future be done under the strict environmental and social laws of the U.S. and Canada, and under the watchful eye of North Americans keeping close tabs on what is going on in their backyards, or exported to countries with low regard for the environment and human rights?

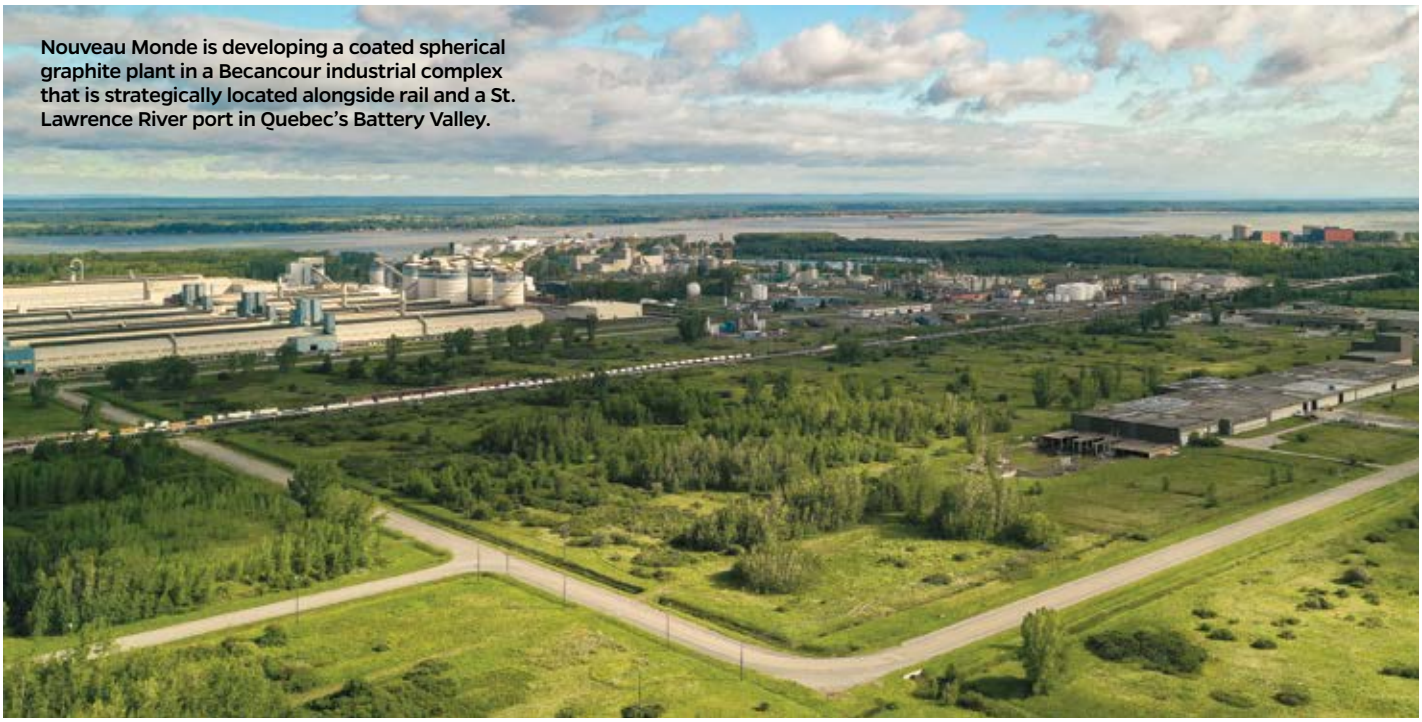
The social and environmental issues associated with supplying the minerals critical to building America's low-carbon dreams were addressed by Ford Motor Company CEO Jim Farley.

"We have to bring battery production here, but the supply chain has to go all the way to the mines," he said during an interview with Detroit News. "That's where the real cost is, and people in the U.S. don't want mining in their neighborhoods. So, are we going to import lithium and pull cobalt from nation-states that have child labor and all sorts of corruption, or are we going to get serious about mining?"

Beyond the exportation of social and environmental issues, there are economic and geopolitical implications of being heavily dependent on imports of minerals and metals.

"America is in a race against economic competitors like China to own the EV market – and the supply chains for critical materials like lithium and cobalt will determine whether we win or lose," said U.S. Secretary of Energy Jennifer Granholm. "If we want to achieve a 100% carbon-free economy by 2050, we have to create our own supply of these materials, including alternatives here at home in America."

Critical Mineral Alliances 2022 offers in-depth insights into more than 30 minerals and metals needed to build the low-carbon and high-tech future, current and potential North American sources of these elements of innovation, and the efforts being made to leverage the rich mineral deposits found in Canada and the U.S. to build the next great human Age. DMN



Nouveau Monde is developing a coated spherical graphite plant in a Becancour industrial complex that is strategically located alongside rail and a St. Lawrence River port in Quebec's Battery Valley.

NOUVEAU MONDE GRAPHITE INC.

Canada to feed a minerals hungry world

Develops strategy to be critical minerals supplier of choice

By SHANE LASLEY
DATA MINE NORTH

UNDERSTANDING THAT THE RENEWABLE energy and electric vehicle revolution offers a "generational opportunity for Canada and its world-class mining sector," Ottawa is leveraging the nation's wealth of critical minerals to become a powerhouse that feeds critical minerals into resource-hungry clean energy and technology supply chains.

"Canada's Critical Minerals Strategy will position Canada as the global supplier of choice for the critical minerals and materials needed for the green, digital global economy," Canada Minister of Natural Resources Jonathan Wilkinson said during a June address at the Prospectors & Developers Association of Canada (PDAC) convention in Toronto.

JONATHAN WILKINSON

Ottawa began positioning Canada as a major player at the front end of the emerging green energy supply chains with a list of critical minerals that reads like a catalog of mined commodities needed for the high-tech and low-carbon future – and found in abundance across the Great White North.

While Canada's list of 31 critical minerals contains many of the usual suspects, such as cobalt, graphite, lithium, and rare earths, it also includes the copper, nickel, and zinc that are fundamental to building the envisioned clean energy future.

"As we transition to cleaner, mineral intensive forms of energy, democratic countries are going to need access to stable and secure sources of critical minerals," said Wilkinson. "Clearly, rapid development of these sources is urgently required."

To help meet this urgent need, Canadian provinces and territories are also positioning themselves along renewable energy supply chains – from the establishment of the country's first rare earths mine in Northwest Territories to manufacturing EVs in Ontario made with domestically mined and processed minerals and metals.

$3.8 billion for Canadian mining

To help deliver critical minerals warehoused in Canadian mines and deposits, Ottawa budgeted C$3.8 billion (US$3 billion) to support Canada's mining sector and bolster the supply chain resiliency, especially when it comes to the supply lines leading to lithium batteries and EVs.

This budget includes:

• $1.5 billion for investments in new critical minerals projects –

prioritizing processing, manufacturing, and recycling for key mineral and metal products along the battery and rare earths supply chains.

• $1.5 billion for infrastructure investments to unlock new mineral projects in critical regions, such as Northern Ontario's Ring of Fire.

• $144 million for research and development to support the responsible extraction and processing of critical minerals.

• $80 million for public geoscience and exploration programs to help find the next generation of critical minerals deposits.

• A doubling of the Mineral Exploration Tax Credit for targeted critical minerals such as nickel, copper, cobalt, rare earths, and uranium.

• Renews the Centre of Excellence on Critical Minerals for three more years with an allocation of $10 million.

• Adds $40 million to support northern regulatory processes in reviewing and permitting critical minerals projects.

• $70 million for global partnerships to promote Canadian mining leadership.

"Doubtless, these measures will give Canada a lock on the top spot for global exploration investment and spur new investments across the value chain," Mining Association of Canada President and CEO Pierre Gratton said.

He added that the "budget should also send a strong signal to our allies in the US and Europe that Canada is and will remain a trusted source for responsibly mined and processed materials essential for the world's low carbon future and security."

Canadian strategy, input

With vast critical minerals resources, a world-class mining sector, and C$3.8 billion allotted to seizing the once-in-a-century opportunity offered by the transition to low-carbon energy and transportation, Ottawa turned to its provinces, territories, Indigenous Peoples, mining sector, and other interested stakeholders to help develop Canada's Critical Minerals Strategy.

Leveraging the national and global stage provided by the PDAC mining convention, Wilkinson released a paper aimed at getting the Canadian critical minerals strategy conversation started.

"Every stage of the critical minerals value chain presents an opportunity for Canada: exploration, mining, processing, manufacturing and advanced manufacturing, and recycling. Moreover, these opportunities exist in every region of the country," the natural resources minister penned in the introduction of the Canadian critical minerals strategy discussion paper. "That's why our government has committed to develop a Critical Minerals Strategy, backed by nearly $4 billion in Budget 2022 – a strategy that will address the entire value chain."

The federal government sought input on five key facets of the nation's preliminary critical minerals strategy:

• Economic growth and competitiveness.

• Environmental protection and climate action.

• Enhanced security and partnership with allies.

• Advancing reconciliation.

• Advancing diversity and inclusion.

Based on the input received by Sept. 15, Ottawa is expected to publish Canada's Critical Minerals Strategy by the end of the year.

"I look forward to working with Indigenous Peoples, provinces, territories, industry and stakeholders to finalize a strategy that will create good jobs for Canadians, grow our economy and further Canada's standing on the world stage," Wilkinson wrote.

Canada's first rare earths mine

As Ottawa hammers out Canada's official strategy, critical minerals supply chains are beginning to take shape across the Great White North. This includes the emergence of the first rare earths supply chain in Canada.

This supply chain begins at Nechalacho, a relatively small but very high-grade rare earths mine in NWT that began production in

The aurora borealis lights up the camp at Nechalacho, the first rare earths mine in Canada.

CHEETAH RESOURCES/BILLBRADENPHOTO

Yellowknife's Dene Drummers perform on the catwalk of the Tomra ore sorter ahead of the first bag of rare earth concentrates produced at the Nechalacho Mine in July 2021.

CHEETAH RESOURCES/BILLBRADENPHOTO

2021 – making it the first and thus far only REE mine in Canada.

The very high-grade rare earth ore that comes to the surface at Nechalacho has allowed Vital Metals Ltd. to quickly establish a mine there with a very small environmental footprint.

Vital contracted Nahanni Construction, a Northwest Territories-based dirt moving company majority-owned by the Yellowknives Dene First Nation, to mine high-grade rare earths ore at Nechalacho.

"We are developing Nechalacho using the most sustainable methods possible, which includes the use of local labor so that we can support the communities surrounding our project," said Vital Metals Managing Director Geoff Atkins.

A TOMRA X-ray transmission (XRT) sorter is being used to upgrade the already high-grade ore at Nechalacho to a concentrate that runs above 30% rare earth oxides.

Without the need for a complex processing facility or tailings storage, the Nechalacho Mine is something akin to a gravel quarry – simply mine and crush near-surface rock and sort out the best material with little or no water and zero chemicals.

"Mining is changing. While sorter technology is widely used in diamond mining, this is the first time that sensor-based sorting has been used as a single step to produce a metal ore concentrate. It is much more environmentally friendly," said TOMRA engineer Russell Tjossem, who trained members of the Yellowknives First Nation to operate the sorter.

In the world of rare earths, however, mining is but the first in a three-step process required to separate this suite of 15 technology elements into the individual metals that can be used by industry.

Saskatoon rare earths hub

This second link in Canada's rare earths supply chain is Vital's rare earth carbonate production plant in Saskatoon, Saskatchewan, where they are now being upgraded to a mixed rare earth carbonate.

"We have been a rare earth miner for more than 12 months and now we can commence production of rare earth carbonate," Vital Metals Managing Director Geoff Atkins said in June.

During the commissioning phase, which is slated to be completed in October, Vital expects to produce a 2.5-metric-ton mixed rare earth carbonate sample that is ready for the third link in the rare earths supply chain – separation.

The mixed rare earth product produced in Saskatchewan is being shipped to REEtec, a Norway-based company that has developed an efficient and environmentally sound REE separation technology, for this final stage of processing.

Under an offtake agreement with REEtec, Vital will deliver roughly 500 metric tons of total rare earth oxides to the Northway separation plant by October 2023. This carbonate is expected to contain 187.5 metric tons of neodymium-praseodymium, a pair of rare earths that are a primary ingredient in the powerful neodymium-iron-boron magnets used in EV motors, wind turbine generators, and countless other products.

While Nechalacho rare earths are being sent to Norway, and potentially to Alaska starting in 2024 for separation, Canada will soon have this capability in-house.

Saskatchewan Research Council, which is developing a rare earth processing plant next to Vital's Saskatoon facility, received

$20 million in provincial funding in June to complete the development of facilities able to separate rare earths and produce the metals used in the powerful permanent magnets that go into EV motors, wind turbine generators, and other applications.

"SRC is proud to be a world leader in rare earth element processing and separation technologies which will play an important part in the innovative solutions needed to reach net-zero," said Saskatchewan Research Council President and CEO Mike Crabtree. "This additional funding will support SRC's ability to continue advancing the production of rare earth elements, as well as our capacity to move further down the value chain as we build a rare earth hub in Saskatchewan."

A hub that will add the final link to a complete rare earths supply chain in Canada.

General Motors will soon be producing BrightDrop electric delivery at a facility in Ontario that will be the first full-scale EV manufacturing plant in Canada.

GENERAL MOTORS

Ontario's mines to EVs strategy

While rare earths are vital to efficiently generating and utilizing low-carbon energy, the quantities of this group of elements needed pales in comparison to the mined raw materials needed for lithium-ion batteries. And Ontario is fostering a complete battery supply chain that extends all the way from the mines to the EVs these batteries will go into.

In March, Ontario unveiled a mines-to-market strategy that leverages rich stores of critical minerals in the northern reaches of the province to the robust manufacturing sector in the south.


DOUG FORD

"The Critical Minerals Strategy is our government's blueprint to connect industries, resources and workers in our province's north to the future of manufacturing in the south as we build up home-grown supply chains," said Ontario Premier Doug Ford. "Doing so has never been more important as we secure game-changing investments in our auto sector to build the electric vehicles and batteries of the future using Ontario minerals."

Ontario has deposits of all the major minerals and metals needed to manufacture the lithium-ion batteries that go into these EVs, plus mines and deposits with two dozen other minerals critical to renewable energy, high-tech, and other industrial sectors.

"These are the materials the world wants and needs for a broad array of uses, including smartphones, batteries for electric vehicles, pharmaceuticals, solar cells and advanced manufacturing technologies to name just a few," said Ontario Minister of Natural Resources and Forestry Greg Rickford.

To leverage its rich mineral endowment, Ontario is encouraging mining and processing that will further anchor the downstream EV supply chain.

"Ontario must build its capacity in chemical processing and battery component manufacturing to establish an integrated battery supply chain," the province inked in a report outlining its critical minerals strategy.

Ford, General Motors, Honda, Stellantis, and Toyota already have automotive and parts factories in southern Ontario. With all these automakers transitioning to electrified models over the next 10 to 15 years, the province has a lot of built-in demand for lithium-ion batteries and the minerals and metals they are made from.

Last year, GM announced that it is investing roughly C$1 billion (US$780 million) to convert an existing auto assembly plant in Ontario into Canada's first large-scale EV manufacturing facility.

To help supply the battery raw materials that will be needed for this and other EV plants, the province has invested in Frontier Lithium's innovative lithium extraction process for lithium and C$5 million to support the production of battery-grade cobalt sulfate at Electra Battery Materials Corp.'s cobalt refinery.

The province is also investing C$250,000 to support the development of a battery-grade nickel sulfate battery precursor cathode active materials plant at a future battery materials park being developed around Electra's cobalt refinery.

"Ontario is home to North America's only battery grade cobalt refinery, an abundance of nickel and clean hydroelectric power," Electra Battery Materials CEO Trent Mell said earlier this year. "Together we can leverage Electra's existing footprint and the Government of Ontario's ambitions to build a world class battery supply chain in the province."

Battery Valley emerges in Quebec

Much like its neighbor to the west, Quebec has emerged as a major link in North America's lithium-ion battery supply chain.

This is especially true for the area around Becancour, a small Quebec town along the shores of the St. Lawrence River about midway between Montreal and Quebec City, which has attracted some of the biggest names in North America's burgeoning lithium battery and EV sectors.

General Motors, POSCO Chemical, and BASF have announced plans to develop lithium battery cathode active materials and recycling plants in this strategic Quebec locale. These global corporations join Nouveau Monde Graphite Inc., a Canadian mining company building a facility at Becancour that produces the coated spherical purified graphite that goes into the anode side of lithium-ion batteries.

The Becancour industrial park where

these and other battery materials companies are setting up shop has quickly earned the name Battery Valley.

BASF says Becancour offers the ideal combination of highly efficient logistics for delivering battery materials to both North America and Europe and has ready access to hydroelectricity that will lower the carbon footprint of products produced there, an advantage that can be passed on to the battery and EV sectors.

Battery Valley also happens to be in an area of eastern Canada that is rich in the minerals and metals needed for battery material manufacturing, which is why Nouveau Monde blazed the trail to Becancour, which lies about 100 miles (165 kilometers) from the company's Matawinie graphite mine.

Nouveau Monde's Becancour plant is being built to produce 42,000 metric tons of spherical coated anode graphite per year and is designed for expansion to keep pace with battery demand.

Becancour's status as Battery Valley was further cemented when GM announced that it is working with POSCO Chemical to develop a roughly $400 million cathode active materials plant there.

"With this new processing facility in Bécancour, GM will help lead the EV battery supply chain while also launching Canada's first full EV manufacturing plant in Ingersoll, Ontario, later this year," said GM Canada President and Managing Director Scott Bell.

GM and POSCO's decision to build this cathode materials plant in Becancour is in line with Quebec's ambitions.

"First, we want to exploit and transform Quebec's minerals to manufacture battery components. Second, we want to produce the cells that will power the assembly plants. Third, we want to develop battery recycling using Quebec technologies. Finally, we want to increase the production of commercial electric vehicles," said Quebec Minister of Economy and Innovation Pierre Fitzgibbon.

Furthering Quebec's four-part strategy, BASF signed an agreement to secure a large land package in Becancour to develop its own cathode active materials production facility, as well as future plants that will recycle battery materials and refine the metals needed for cathodes.

"This land acquisition is a necessary prerequisite to further advance our strategy to grow our footprint in key regions to better serve our customer's operations with sustainable and reliable local supply," said Peter Schuhmacher, president of the catalysts division at BASF. "We look forward to supporting the e-mobility transition in the United States, Canada, Mexico and beyond."

Canada's Industry Minister Francois-Philippe Champagne hinted that there could be more EV-related companies moving into Quebec's Battery Valley.

"We're building around Becancour kind of the full ecosystem of the critical minerals you need to produce a battery ... that's why you'll see more to come," he said.

Electra Battery Materials is in talks with Quebec government officials about setting up a cobalt refinery similar to its Ontario facility in Battery Valley. The Quebec economy minister says he also met with Tesla executives late last year to discuss where the province fits into the iconic EV manufacturer's EV ambitions.

Considering how active Tesla has been along the entire EV and battery materials supply chain, a hub in Becancour and its proximity to battery raw materials, low-carbon electricity, and infrastructure would not be a surprise. DMN

ROB WIDDIS FOR GENERAL MOTORS

President Joe Biden at General Motors' Factory Zero electric vehicle assembly plant in Michigan.

The kryptonite of America's economy

Lack of critical minerals weakens US clean energy ambitions

By SHANE LASLEY
DATA MINE NORTH

THE WHITE HOUSE AND LAWMAKERS on Capitol Hill are becoming increasingly aware that a lack of secure supplies of critical minerals and metals may be the kryptonite that weakens America's economy, national security, and clean energy ambitions.

"The more we dive into this topic of critical minerals, the more I'm certain Superman isn't the only one who can be brought to his knees by rare minerals," quipped Sen. Joe Manchin, D-West Virginia, during an April hearing on critical minerals demand and recycling.

JOE MANCHIN

As chairman of the U.S. Senate Energy and Natural Resources committee, Manchin has heard testimony from seemingly endless panels of experts warning about the United States' dependence on countries like China and Russia for the rare earths, lithium, nickel, and a long list of other minerals and metals critical to the U.S.

"We wouldn't be talking about critical minerals – in fact, they wouldn't be considered critical at all – if it weren't for the 'stuff' that they go into. And the 'stuff' happens to be critically important for the U.S. economy and national security," Abigail Wulf, vice president of critical minerals strategy at Washington D.C.-based Securing America's Future Energy, said during an April hearing before Manchin's committee. "This 'stuff' includes batteries, semiconductors, electric vehicles, renewable energy, and advanced

weapons systems – all of which are made of and powered by minerals and mined materials. We are only going to need more of these things as the world increasingly transitions to an electric, connected, and autonomous future."

The understanding that America needs to develop reliable supplies of critical minerals goes beyond conservative think tanks and lawmakers from mineral-rich states. The White House has become increasingly active in pursuing reliable supplies of the minerals required to build its envisioned low-carbon energy and transportation future.

While the Biden administration's recognition that the U.S. is over-reliant on oft adversarial countries for the critical raw materials required to "build back better," breaking this dependence in time to manufacture the EVs, wind turbines, solar panels, lithium-ion batteries, and other stuff required to meet the White House's clean energy ambitions will require a bipartisan effort in Washington, D.C.

ConservAmerica, a Washington D.C.-based conservation group, called America's dependence on critical mineral imports "one of the nation's most persistent and pervasive national security and economic challenges."

"We appreciate the administration's recognition that federal policy is key to solving America's deepening dependence on foreign countries, particularly China, for minerals essential to our economy," said ConservAmerica President Jeff Kupfer. "China will not, and has not been playing the slow game. We cannot afford to either."

Resembling the fictional mineral kryptonite, emeralds are made from beryllium, aluminum, and trace amounts of chromium or vanadium – all minerals critical to the U.S.

Common ground in DC

The White House and both sides of the aisle on Capitol Hill have found some common ground when it comes to hastening domestic critical minerals production.

In March, a bipartisan group of U.S. senators – Lisa Murkowski (R-Alaska); Senate Energy and Natural Resources Committee Chairman Joe Manchin (D-West Virginia), Jim Risch (R-Idaho), and Bill Cassidy (R-Louisiana) – sent a letter urging President Biden to invoke the Defense Production Act, or DPA, to accelerate domestic production of lithium-ion battery materials, in particular graphite, manganese, cobalt, nickel, and lithium.

Established at the onset of the Korean War, DPA allows American presidents, largely through executive order, to direct private companies to prioritize orders from the federal government.

To bolster domestic production of materials critical to national security, the President may also offer loans or loan guarantees to companies, subject to an appropriation by Congress.

"The authorities provided to you as President under the Defense Production Act will help to ensure that America's critical mineral supply chains are strong, responsibly produced, and ethically sourced. Given the stakes, America cannot afford to wait any longer for that day to arrive," the senators wrote.

This sense of urgency is being driven by America's dependence on often rival nations for a wide array of critical minerals and metals.

According to a January report by the United States Geological Survey, the U.S. was dependent on imports for more than half its supply of 47 nonfuel mineral commodities and 100% import-reliant for 17 of those during 2021.

"The concentration of where that supply comes from makes our foreign dependence even more concerning," the senators penned in their letter. "China dominates the international critical mineral supply chain, presenting a dire national security threat for the United States, and harsh economic realities for American manufacturers."

DPA funding for battery materials

Less than a month after receiving the senators' letter, Biden authorized the use of DPA funding to "secure American production of critical materials to bolster our clean energy economy by reducing our reliance on China and other countries for the minerals and materials that will power our clean energy future."

"Specifically, the DPA will be authorized to support the production and processing of minerals and materials used for large capacity batteries – such as lithium, nickel, cobalt,

ADOBE STOCK

graphite, and manganese – and the Department of Defense will implement this authority using strong environmental, labor, community, and tribal consultation standards," the White House penned in a March 31 briefing.

In a memorandum ordering the Pentagon to authorize the use of DPA funding and authorities to support the domestic production of critical battery materials, President Biden echoed concerns of the lawmakers that urged him to do so.

"The United States depends on unreliable foreign sources for many of the strategic and critical materials necessary for the clean energy transition – such as lithium, nickel, cobalt, graphite, and manganese for large-capacity batteries. Demand for such materials is projected to increase exponentially as the world transitions to a clean energy economy," he penned in the memorandum.

The memo orders the Pentagon to utilize Defense Production Act Title III funding to establish and expand upon sustainable and responsible domestic strategic and critical minerals production.

Unions and mining companies came out in support of the President's use of DPA Title III funding and authorizations for critical battery metals.

United Steelworkers International President Tom Conway said union members across North America already produce many of the materials addressed by the DPA order and stand ready to further "mine, produce and recycle lithium, cobalt, manganese, nickel, graphite and other critical minerals as we build out and secure our own domestic supply chains."

Russia war increases urgency

While the use of DPA to bolster domestic production of battery materials was hailed as a win for onshoring lithium-ion battery supply chains, many say that there is much more to be done to curb America's heavy dependence on oft adversarial countries for the minerals and metals critical to the nation's security and economic wellbeing.

Manchin, who has long been sounding the alarm on America's dependence on China and others for minerals deemed critical to the U.S., believes Russia's invasion of Ukraine raises the national security implications of this import-reliance.

"Building out our domestic supply chain and reducing our reliance on Russia, China and other adversarial nations is more important than ever before," he penned in a statement. "I urge the administration to continue using all the tools at their disposal and working with Congress to unlock the full potential of our nation's vast natural resources to deny any nation the ability to use supply chain dependencies against us and our allies."

Russia is a major supplier of many of the minerals critical to low-carbon energy generation and storage –antimony, nickel, uranium, and vanadium are high on this list.

In a June National Defense Authorization Act report, the U.S. House Armed Services Committee said it "is concerned about recent geopolitical dynamics with Russia and China and how that could accelerate supply chain disruptions, particularly with antimony."

The Senate Armed Services Committee is also concerned about the geopolitical consequences of being dependent on China and Russia for antimony and other critical minerals.

"America's defense in the modern era increasingly demands the use of critical minerals, making it more essential by the day for our nation to have a sufficient stockpile of and reliable access to these materials," said Sen. Joni Ernst, R-Iowa, a combat veteran that serves on the Senate Armed Service Committee. "At this very moment, our enemies like China dominate the supply chain of these increasingly vital materials, and are even expanding into regions such as Africa and Afghanistan, threatening our readiness in an emergency situation and jeopardizing our national security."

Senators Ernst and Manchin introduced the Homeland Acceleration of Recovering Deposits and Renewing Onshore Critical Keystones (HARD ROCK) act in June.

This legislation is designed to bolster the National Defense Stockpile of strategic and

U.S. ARMY, SGT. STEVEN LEWIS

Russia's war with Ukraine has heightened concerns about America's dependence on imports for minerals critical to the nation's military readiness.

critical materials needed for national security.

"America is blessed with an abundance of natural resources that can help us address our reliance on foreign supply chains for critical minerals," said Manchin. "By addressing the weaknesses in our current National Defense Stockpile, our bill will bolster American critical mineral independence and help ensure we have the resources we need for essential defense products and services."

In addition to the HARD ROCK Act, the Senate National Defense Authorization Act includes $1 billion in funding to support the Defense Logistics Agency's acquisition of critical materials for the National Defense Stockpile.

Solving the permitting logjam

There is a growing consensus on Capitol Hill that much more must be done to establish domestic supplies of the minerals critical to America, especially when it comes to the nearly decade-long process to permit a mine in the U.S.

"We cannot go from a dependency on foreign oil to a dependency on Chinese minerals," said Sen. Cassidy. "It is encouraging that the administration listened to our letter and is announcing action. However, enacting the DPA without addressing the bureaucratic logjam of permitting would be little more than symbolism. We have to also streamline the permitting process that could delay any effort by years."

Considering it takes an average of seven to 10 years, and often longer, to permit a mine in the U.S., Cassidy's "bureaucratic logjam" concerns are well-founded.

Under America's current process, a battery metals mine entering the federal permitting process today would likely not begin offering a domestic supply of these critical minerals until around the mid-2030s.

Sen. Murkowski, who has been leading the charge to streamline mine permitting in the U.S. for more than a decade, has often pointed to Canada and Australia as examples of countries with strong environmental standards that permit mines in two to three years.

While hailing Biden's invocation of the DPA to strengthen domestic critical battery mineral supply chains as important, the Alaska senator urges the White House to address permitting and other challenges hampering America's mining sector.

"My hope is that this decision marks the start of a much more serious emphasis on our nation's mineral security, and that real projects, especially mines, in states like Alaska, result from it," she said. "It is also critical that the five minerals addressed under this decision are just the start, not the end, of federal efforts to rebuild our domestic supply chains."

A growing chorus of voices from both sides of the aisle on Capitol Hill has joined the call to streamline America's long mine permitting process in a way that does not sacrifice environmental protections.

Representing the middle of this group, Sen. Angus King (I-Maine) contends that American ingenuity is the answer.

"What we are talking about today is a solvable problem – we need these minerals and to cut our dependence on hostile countries; we need to protect our natural environment, resources, and communities – this is an engineering problem," said King. "I want the strongest most far-reaching environmental mines in the country and the most timely and predictable permitting process – it should not be used to stop projects. We need one-stop permitting and government coordination." DMN

The 2022 U.S. Geological Survey critical minerals list includes 50 minerals and metals essential to the economic wellbeing and national security of the United States.

PIXABAY

Critical minerals are not set in stone

Supply, demand and supply chain risks defines criticality

By SHANE LASLEY
DATA MINE NORTH

METAPHORICALLY SPEAKING, critical minerals are not set in stone. Instead, the criticality of these basic building blocks of modern society shifts with the demands for any given mineral, the ability of the mining sector to keep pace with that demand, and the geopolitics of where that supply comes from.

"Mineral criticality is not static, but changes over time," said Steven Fortier, director of the National Minerals Information Center at the United States Geological Survey.

The critical minerals landscape has been particularly dynamic with America's shift to electric vehicles and renewable energy, sectors of the economy that have created massive new demand for many minerals and metals that were previously considered niche.

Lithium is a prime example. Just 20 years ago, it only took around 15,100 metric tons of lithium to meet the global demands of this metal that was primarily used in ceramics, glass, lubricants, and aluminum production. The roughly 100,000 metric tons produced during 2021, however, was not enough as this lightest of the metals has become increasingly critical to the batteries that bear its name.

The everchanging swings in supply, demand, geopolitical risks, and trade policy are reflected in the USGS's list of 50 minerals deemed critical to the U.S.

"The 2022 list of critical minerals was created using the most recent available data for non-fuel mineral commodities," Fortier said. "However, we're always analyzing mineral markets and developing new methods to determine the various and evolving critical mineral supply chain risks."

Defining critical minerals

The terms critical minerals and strategic minerals can be traced back to World War I, when it became clear that the U.S. needed to bolster supplies of certain metals and minerals to support the war effort. Over the ensuing century, however, the definitions of these overlapping terms have been somewhat subjective and been interpreted differently by various agencies and individuals depending on their priorities.

In the U.S., critical minerals became a little less subjective with a 2017 definition that effectively merged critical and strategic metals, while also offering the flexibility for a list of critical minerals to shift with society.

Nickel and zinc, two newcomers to the list of minerals and metals critical to the U.S., are important building blocks for renewable energy generation and storage.

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Under this definition, a mineral is considered critical if it is essential to the economic and national security of the United States; vulnerable to supply chain disruptions; and serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for the U.S. economy or security.

In 2018, USGS established an inaugural list of 35 minerals and metals critical to the U.S.

Due to the everchanging state of mineral demands and global geopolitics, the Energy Act of 2020 directed the Department of the Interior, which presides over USGS to review the critical minerals list, to update the methodology used to determine the criticality of minerals and metals, gather feedback from the other federal agencies and public, and ultimately finalize a revised list of critical minerals at least every three years.

This led the USGS to draft up a new list of 50 critical minerals and metals that reflects the new shifting landscape for these commodities.

"The USGS's critical minerals list provides vital information for industry, policymakers, economists and scientists on the most important minerals when it comes to U.S. supply chains," said Tanya Trujillo, Assistant Secretary of the Interior for Water and Science. "The statistics and information are crucial to understanding America's vulnerability to disruptions in the supply of critical minerals, including data on the worldwide supply and demand for minerals and materials essential to the U.S. economy and national security."

Separating REEs, PGMs

While critical minerals are not static, they are not as dynamic as the roughly 40% increase from 35 to 50 commodities might suggest. Most of the newcomers to USGS's 2022 list are from individualizing the elemental constituents of two mineral groups – rare earths and platinum group metals.

Traditionally thought of as a single entity, rare earths are actually a group of 15 elements that make up the second row from the bottom on the periodic table – each with its own distinct traits, uses, and markets.

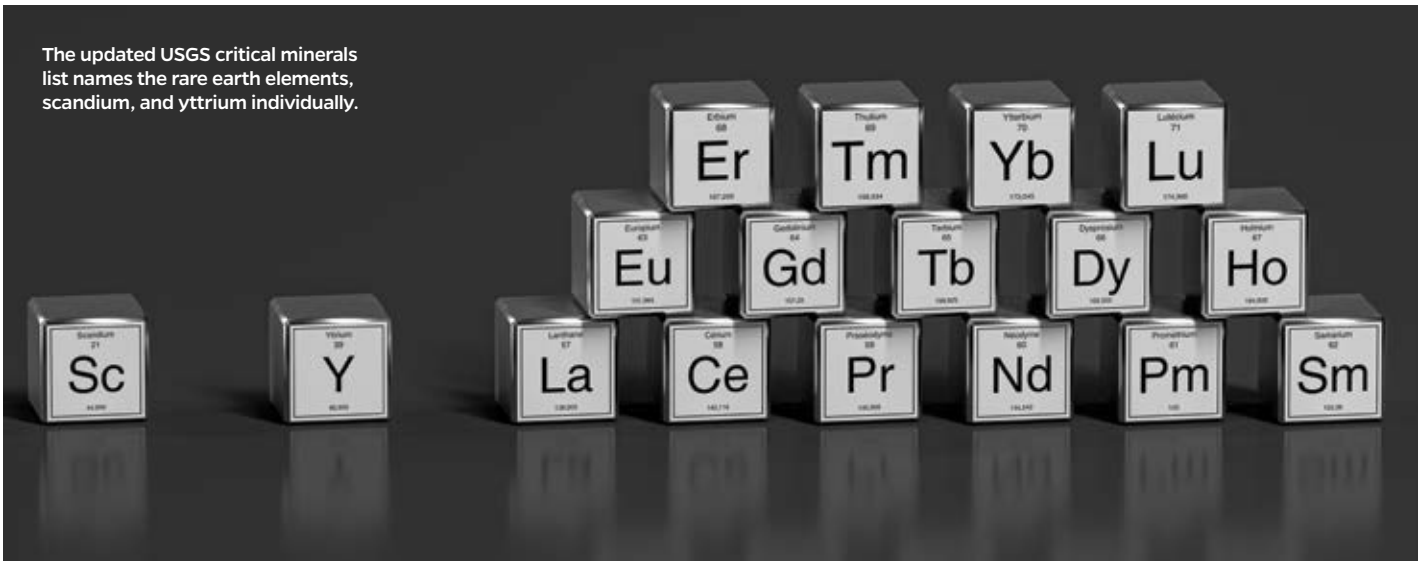
With the exception of promethium, which is an unstable element with a naturally occurring abundance in Earth's crust estimated to be less than 600 grams at any given time, the 2022 critical mineral list considers each REE as a critical mineral in its own right.

Scandium and yttrium, which are often also considered rare earths due to similar properties and geological affinities to the lanthanides, are listed separately on both the 2018 and 2022 critical minerals lists.

USGS's original critical minerals list also considered the group of six platinum group metals as one commodity. The 2022 list names five of them – iridium, platinum, palladium, rhodium, and ruthenium – as critical to the U.S.

Surprising newcomer, omission

While breaking up the rare earth elements and platinum group metals



The updated USGS critical minerals list names the rare earth elements, scandium, and yttrium individually.

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account for most of the U.S. critical minerals list expansion, there are two major additions – nickel and zinc.

Due to its importance to lithium-ion batteries, it is no surprise that nickel made the list.

The International Energy Agency forecasts that under a scenario where low-carbon energy generation and electric vehicles are adopted at a pace to meet the climate objectives of the Paris Agreement, nickel demand will rocket from roughly 2.4 million metric tons in 2021 to 4.6 million metric tons by 2030 and continue climbing to 6.3 million metric tons by 2040.

Less than a month after officially deemed critical to the U.S., nickel captured headlines when the price of this battery metal rocketed 250% to a brief altitude above US$100,000 per metric ton, or US$45 per pound, in a span of two days.

While a market overreaction triggered by the sanctions on Russia, which accounted for nearly 10% of global nickel supply during 2021, over its invasion of Ukraine, this temporary sharp rise in nickel price and the geopolitical factors behind it demonstrate how quickly the criticality of a metal can shift.

■ *Further details on the growing demand for nickel can be read at* ***More low-carbon nickel the plea for 2022*** *on page 22.*

While not as high-profile or volatile as nickel, zinc is an important ingredient in the renewable energy revolution, as well as the Biden administration's $1.2 trillion infrastructure bill.

An oft-overlooked industrial metal, zinc plays a central role in the low-carbon future due to its use in galvanizing renewable energy infrastructure against weathering. Zinc is particularly demanded by wind power generation, which needs about five metric tons of this metal for every megawatt of power generating capacity, according to the IEA.

These same galvanizing qualities will be needed for the bridges, culverts, guardrails, light poles, 5G network towers, and other upgrades to be funded by the massive infrastructure bill passed by Congress and waiting to be signed into law by President Joe Biden.

In addition to its importance to infrastructure, zinc is arising as an intriguing new lower-cost option for storing the intermittent renewable energy generated by wind and solar.

Five commodities deemed critical to the U.S. in 2018 – helium, potash, rhenium, strontium, and uranium – were removed from the 2022 list.

■ *Further details on the growing criticality of zinc in the United States can be read at* ***Zinc galvanizes US Critical Minerals list*** *on page 96.*

The removal of uranium is considered the most controversial by many who tout nuclear power as an important facet for transitioning to zero-carbon electricity.

The USGS, however, says this omission has more to do with the U.S. definition of critical minerals as to do with uranium's criticality.

"Uranium was not evaluated because the Energy Act of 2020 explicitly excluded 'fuel minerals' from the definition of a 'critical mineral,'" the geological survey explained in a FAQ sheet associated with the draft list of critical minerals.

"The 2022 list of critical minerals was created using the most recent available data for non-fuel mineral commodities," Fortier said. "However, we're always analyzing mineral markets and developing new methods to determine the various and evolving critical mineral supply chain risks." DMN

TESLA INC.

Electric vehicles, such as this Tesla Model X, boast sophisticated infotainment, driver-assist, navigation, diagnostics, and other advanced digital systems.

Minerals critical to the EV Revolution

EVs require six times the minerals than their ICE forebearers

By SHANE LASLEY
DATA MINE NORTH

WITH EVEN THE MOST BASIC models boasting sophisticated driver-assist, navigation, infotainment, diagnostics, and other advanced digital systems being fed power from oversized versions of the lithium-ion batteries found in your laptop or smartphone, electric vehicles are becoming personal computers that you can drive around.

While this puts a whole new spin on the term mobile computing, riding around in a zero-emissions vehicle with enough processing power to put your PC to shame, especially autonomous models that are estimated to have the computing power of 200 laptops, means that EVs need a lot more critical minerals than their internal combustion engine forebearers.

Setting aside the aluminum and steel common to both, the International Energy Agency estimates that the EVs of tomorrow require more than six times the minerals and metals than ICE vehicles of yesteryear.

Between the electric motors, lithium-ion batteries, cutting-edge infotainment systems, and high-strength alloys, the average EV requires roughly 25 of the 50 minerals and metals that have been deemed critical to the United States.

Beyond the critical minerals, electric cars, trucks, and SUVs need a little gold and silver for the circuit boards and critical electrical connections, and a whole lot of copper to wire everything together.

With global automakers expected to be producing roughly 30 million electric vehicles per year by 2030 and as many as 82 million by 2040, the burgeoning EV revolution is demanding that global mining companies rapidly scale up supplies for the gamut of industrial, precious, and critical minerals that go into these computers-on-wheels.

Ravenous battery materials appetite

Automakers transitioning their assembly lines from the petroleum-fueled vehicles of the past to the electric cars of the future currently have a particularly ravenous appetite for the minerals and metals that go into the lithium batteries powering these modern transportation marvels.

With a growing number of smartphones, laptops, tools, kitchen

Right: If global automakers meet electric mobility targets, they will be producing roughly 30 million electric vehicles per year by 2030 and as many as 82 million by 2040. **Below:** General Motors is securing reliable supplies of raw materials critical to its Ultium battery and electric drive platform.

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gadgets, and plethora of other cordless electronics, lithium-ion batteries have become an integral component of how we live, work, and play. Adding how we travel to this list, however, is driving exponential growth in the demand for these rechargeable batteries, and the materials they are made of.

It simply takes a lot more energy to roll down the highway at 65 miles per hour than it does to call a friend, check your business email, or send a Tweet.

For example, the lithium-ion battery powering a standard range Tesla Model 3 weighs in at just over 1,000 pounds. That is equal to about 500 laptop or 8,000 smartphone batteries.

So, while our increasingly cordless world has driven enormous demand for lithium-ion batteries and the materials they are made of over the past two decades, this pales in comparison to what is going to take to trade in the roughly 1 billion ICE vehicles currently traversing global highways to the smarter EVs of the future.

"The supply chain is geared for making batteries for laptops and mobile phones, it is not geared for making batteries for the size of a car," said Simon Moores, founder of Benchmark Mineral Intelligence, a global leader in lithium battery supply chain analysis.

To scale up the lithium battery sector to meet the demands of the EV revolution, automakers and battery manufacturers are building gigafactories around the world – giga standing for the multimillion watt-hours of battery storage each one of these facilities will be churning out each year.

Benchmark is tracking more than 300 of these super-sized lithium-ion battery factories in various stages of development to meet EV demand.

Batteries out of these gigafactories mean giga-scale quantities of minerals and metals being fed in.

While each battery and automaker has its own special formula, the average lithium-ion battery powering a sedan-sized EV needs around 146 lb of graphite, 88 lb of nickel, 29 lb of cobalt, and 20 lb of lithium.

Based on current formulas and technologies, EV batteries alone would need around 12 billion lb of graphite, 7.2 billion lb of nickel, 2.4 billion lb cobalt, and 1.6 billion lb of lithium per year by 2040 in order to manufacture enough of these computers on wheels to meet global government and

GENERAL MOTORS

automaker goals.

This equates to five times more graphite, 20% more nickel, six times more cobalt, and seven times more lithium than was produced at every mine on Earth during 2021.

To scale up the gigafactory inputs at this scale, Benchmark's Moores says automakers will "need to become miners" – investing both their money and influence into ensuring there are enough materials to build their vision of getting everybody into a battery-powered computer on wheels.

This is not lost on automakers that are increasingly investing in the mining companies that will supply the building blocks of the EV revolution and lending their voice to a growing chorus calling for more mining in countries with strong environmental and human rights standards.

"We have to bring battery production here, but the supply chain has to go all the way to the mines," said Ford Motor Company CEO Jim Farley. "That's where the real cost is, and people in the U.S. don't want mining in their neighborhoods. So, are we going to import lithium and pull cobalt from nation-states that have child labor and all sorts of corruption, or are we going to get serious about mining?"

With battery metal prices skyrocketing, Tesla CEO Elon Musk is getting serious about mining – suggesting that the renowned electric automaker might need to get into the business of digging up the rocks with the minerals required to meet the demands of its growing EV production.

"Price of lithium has gone to insane levels!" Musk tweeted on April 8. "Tesla might actually have to get into the mining & refining directly at scale, unless costs improve."

Rare earths on the EV priority list

Ingredients for the lithium batteries powering the EV revolution are not the only mined materials keeping auto executives up at night. Responsible and secure supplies of the rare earth elements that transform the electricity stored in those batteries into motion – at the same time delivering high-fidelity sound from the state-of-the-art infotainment system – are also high on the priority list.

When it comes to EVs, the biggest use for rare earths is in the motors that silently deliver enough torque to the ground to rocket a Ford Lightning, the electric version of the classic F-150 pickup, from 0 to 60 in about 4.4 seconds.

While automakers are looking at alternatives for EV motors, there are no options currently available that deliver this kind of power to the ground as effectively and efficiently as those equipped with powerful rare earth magnets.

The problem is these magnets are almost exclusively made in China, a country not highly regarded for its environmental protections, which has been known to leverage its near-global monopoly of these tech elements for geopolitical purposes.

While mines outside of China, including MP Materials Corp. Mountain Pass operation in California's Mojave Desert, are beginning to produce rare earths, the Middle Kingdom still dominates the ability to separate the mix of 14 rare earths produced at these mines into the individual elements critical to a broad array of modern technologies and then upgrading some of the REEs into the powerful permanent magnets the electric automakers need and want.

Looking to bypass China, General Motors has cut a deal to buy rare earth materials and magnets to be produced at a new facility MP Materials is building in Texas.

This 200,000-square-foot rare earth metal and magnet manufacturing plant, which is slated to begin ramping up production in 2023, will initially have the capacity to produce roughly 1,000 metric tons of finished neodymium-iron-boron magnets per year, enough for approximately 500,000 EV motors.

MP Materials Chairman and CEO James Litinsky says the involvement of automakers is vital to establishing a sustainable and secure supply of rare earth magnets.

"Restoring the full rare earth supply chain to the United States at scale would not be possible without U.S. manufacturers like GM recognizing the strategic consequence and

The price of lithium carbonate, such as that being extracted from brine at the Salinas Grandes salt flat in northern Argentina, has increased by more than 10-fold since the beginning of 2021.

KSENIYA RAGOZINA; ADOBE STOCK

>> Based on current formulas and technologies, EV batteries alone would need around 12 billion lb of graphite, 7.2 billion lb of nickel, 2.4 billion lb cobalt, and 1.6 billion lb of lithium per year by 2040 in order to manufacture enough of these computers on wheels to meet global government and automaker goals.

acting with conviction," he said.

GM's conviction includes several similar partnerships aimed at creating scalable, resilient, sustainable, and North American-focused supply chains for the materials needed to build at least 1 million EVs in North America alone.

"We are building a resilient and sustainable EV manufacturing value chain in North America, from raw materials to cell manufacturing to electric drive motors and beyond, further accelerating GM's vision to support a mass market for EVs," said Shilpan Amin, vice president of global purchasing and supply chain at GM. "Our work with MP Materials is another bold step forward that will help ensure that we meet our goal to lead the EV industry in North America in more than just sales."

■ *Further details on the companies behind the effort to establish a mines-to-magnets rare earth supply chain in North America can be read at* ***Seven world transforming rare earths*** *on page 58.*

Swift mining investments needed

Whether it is the minerals and metals needed for lithium-ion batteries, the rare earths that transform energy stored in those batteries into motion, or the array of other minerals critical to manufacturing electric vehicles that are as much about computing power as horsepower, the International Energy Agency urges swift investments into mines and other suppliers of these critical raw materials.

In its "Global EV Outlook 2022" report, IEA points out that demand for lithium is projected to increase sixfold to 500,000 metric tons by 2030 if enough batteries are going to be manufactured for EVs and to store enough intermittent renewable energy to meet the climate pledges of global governments. This means that the equivalent of 50 new average-sized lithium mines would need to be developed over the next eight years.

Benchmark Mineral Intelligence, the foremost authority on lithium-ion battery supply chains, estimates that US$42 billion of investment will need to be made in the lithium sector by 2028 to meet the forecast 2030 demand.

While lithium is experiencing the largest percentage growth due to the previously small market, the tonnage of graphite, nickel, and even cobalt being demanded for lithium-ion batteries eclipses the namesake metals.

Considering the long lead times for permitting and developing a mine, especially in countries with strong environmental standards, global commodity experts agree that investments in the suppliers of rare earths, battery raw materials, and other critical EV minerals need to happen quickly to meet the downstream demands.

"Pressure on the supply of critical materials will continue to mount as road transport electrification expands to meet net zero ambitions," IEA wrote. "Additional investments are needed in the short term, particularly in mining, where lead times are much longer than for other parts of the supply chain."

If the required large mining investments are not made soon enough, a shortage of energy minerals will likely mean that global climate targets will not be met, and the costs of building the low-carbon electric grids and the EVs that plug into them will be higher than hoped. DMN

General Motors is securing low-carbon lithium for its Cadillac, Chevrolet, GMC, and BrightDrop electric vehicles.

GENERAL MOTORS

Automakers move into lithium mining space

GM, Stellantis, Tesla moving further up battery supply chain

By SHANE LASLEY

DATA MINE NORTH

WITH THE BATTERIES POWERING the electric vehicle revolution demanding more lithium than miners can produce, the price of this lightest element in the universe rocketed more than 1,000% over the span of two years. This has prompted automakers such as Tesla and General Motors to become more directly involved in the mining and refining of the lithium-ion battery namesake.

"Price of lithium has gone to insane levels! Tesla might actually have to get into the mining & refining directly at scale, unless costs improve," Tesla CEO Elon Musk tweeted in April. "There is no shortage of the elements, as lithium is almost everywhere on Earth, but pace of extraction/refinement is slow."

This contemplation of lithium mining coincided with the opening of Gigafactory Texas, an automotive plant near Austin that is also expected to be home to one of the world's largest lithium-ion battery factories.

This marks the fifth large battery plant built by Tesla since the 2016 opening of Gigafactory 1 in Nevada, which set the stage for the global rise of lithium battery factories built at the gigawatt-hour scale needed to keep pace with the rapid transition to electric mobility.

According to Benchmark Minerals Intelligence, a United Kingdom-based analytics firm that is considered the foremost authority on lithium battery supply chains, global lithium battery production has surged from 59 GWh per year in 2015 to 1 terawatt-hour, or 1,000 GWh, at the end of 2021.

With more than 300 such gigafactories in various stages of planning and construction, Benchmark sees even sharper rises in battery production on the horizon, as long as enough lithium and other battery materials can be fed into the supply chains.

This is a tall order for mining companies, which are already falling behind.

According to Benchmark, roughly 5 million metric tons of lithium carbonate-equivalent – an industry standard for comparing various forms of lithium produced – would be needed to supply the battery megafactories in the pipeline. This is more than ten times the 480,000 metric tons of lithium carbonate-equivalent produced globally during 2021.

Simon Moores, CEO of Benchmark Mineral Intelligence, and Morgan Bazilian, director of the Payne Institute and professor of public policy at Colorado School of Mines, believe that automakers will need to directly support mining with their financial wherewithal and political clout in order to feed the battery factories powering their EV ambitions.

"Big talk on EVs must now mean equally as big statements on mining," the battery minerals and policy experts penned in an April editorial directed at automakers.

Musk's lithium Tweet suggests that the EV trailblazer agrees.

Controlled Thermal Resources' Hell's Kitchen project has the potential to produce up to 1,100 megawatts of renewable electricity and 300,000 metric tons of near-zero-carbon lithium from the geothermal resource found there per year.

CONTROLLED THERMAL RESOURCES LTD.

Like minting money

To lure new investment to the lithium space, Musk pointed out huge profit potential of producing the battery metal at the US$78,000 price levels early in 2022.

"So, like we were talking 90% margins here. More people, please, get into the lithium business," he said in April. "Do you like minting money? Well, the lithium business is for you."

While high lithium prices are a concern for Tesla and other automakers attempting to lower the costs of manufacturing batteries to a point where the costs of electric cars and trucks are comparable to the internal combustion engine vehicles they are destined to replace, the supply and demand dynamics that this price increase indicates is the larger worry.

It is estimated that a 30 GWh factory, which is about the size of Tesla's Gigafactory in Nevada, needs roughly 5,000 metric tons of mined lithium for the 25,000 metric tons of lithium carbonate-equivalent going into the batteries each year. At this rate, the 1 TWh of battery-making capacity going into 2022 would require 165,000 metric tons of mined lithium.

This is substantially more than the 100,000 metric tons of lithium produced in 2021. And the battery makers must share this lithium with companies that use the metal to make ceramics and glass, lubricating greases, and other products.

With this demand expected to outpace supply, and larger increases in the need of lithium for batteries on the horizon, automakers are being encouraged to invest more heavily into securing the supplies of lithium and other materials needed to meet their outsized EV ambitions.

"After all, a gigafactory without secure raw materials is as useful to an OEM (original equipment manufacturer) as a grain silo," Moores and Bazilian wrote.

Cooking up lithium in Hell's Kitchen

Automakers are increasingly forging strategic partnerships and investing in the companies mining and refining lithium for EV batteries.

General Motors, which plans to only manufacture zero-emission vehicles by

Mud pots above the lithium-rich geothermal resource at the Salton Sea, California.
CONTROLLED THERMAL RESOURCES LTD.

2035, was among the first automakers to be directly involved at the very front end of lithium supply chains.

In 2021, the Detroit automaker forged a strategic partnership with Controlled Thermal Resources Ltd. to source low-cost and environmentally responsible lithium from the Hell's Kitchen project at the Salton Sea Geothermal Field in Southern California.

Unlike typical lithium sources that require mining or large evaporation ponds, CTR is developing a closed-loop process that directly extracts the critical battery metal from geothermal brine at Hell's Kitchen.

Almost like a self-perpetuating lithium-producing machine, the Hell's Kitchen operation will use the geothermal to power the extraction of lithium and a plant that will upgrade it to the lithium hydroxide used in EV batteries. The lithium-less brine will then be pumped back down into the ground from which it was drawn, and the excess zero-carbon electricity will be delivered to the Southern California power grid.

"Lithium is critical to battery production today and will only become more important as consumer adoption of EVs increases, and we accelerate towards our all-electric future," said Doug Parks, executive vice president of global product development, purchasing and supply chain at GM. "By securing and localizing the lithium supply chain in the U.S., we're helping ensure our ability to make powerful, affordable, high mileage EVs while also helping to mitigate environmental impact and bring more low-cost lithium to the market as a whole."

Hell's Kitchen has a total projected capacity of 1.1 gigawatts of baseload renewable electricity – enough to power more than 1 million homes – and 300,000 metric tons of lithium carbonate-equivalent (an industry standard for comparing various forms of lithium produced) per year.

This source of clean power and lithium has attracted the attention of Lars Carlstrom, a pioneering industrialist in the automotive sector who founded two companies building lithium-ion battery gigafactories in Europe – Britishvolt and Italvolt.

In April, Carlstrom announced the launch of Statevolt, which plans to build a 54 GWh battery facility in the Imperial Valley area of Southern California that will be supplied with geothermal power and lithium from Hell's Kitchen.

"We are pleased to be collaborating with CTR and its industry-leading, and highly-specialized approach to sustainable lithium production and development," said Carlstrom.

Looking to ramp up operations in stages, CTR is planning to deliver the first 49.9MW of electricity by the end of 2023 and produce the first 20,000 metric tons of lithium hydroxide in 2024.

Not to be left out, Stellantis signed a binding offtake agreement with CTR in June for up to 25,000 metric tons of battery-grade lithium hydroxide per year for the batteries going into Chrysler, Dodge, Jeep, Ram, and other electric vehicles it will produce in North America over the ten-year term of the contract.

"This definitive offtake agreement with Stellantis sets a new benchmark for the automotive industry in the United States," said

Controlled Thermal Resources CEO Rod Colwell. "Securing clean lithium produced with energy from a renewable resource helps to further decarbonize the battery supply chain which in turn, delivers cleaner cars with less environmental impact."

Zero Carbon Lithium in Germany

While Hell's Kitchen lithium has become a hot commodity for manufacturing EVs in North America, it is not the only lithium-rich geothermal brine in the world.

Vulcan Energy Resources Ltd., a company developing a geothermal brine production plant at its Zero Carbon Lithium project in Germany's Upper Rhine Valley, has attracted a similar following of automakers seeking responsibly sourced lithium for their European EV models.

Late last year, Volkswagen entered into a long-term agreement to source undisclosed quantities of zero-carbon lithium hydroxide from Vulcan.

"Through this agreement, Vulcan Energy will become a major enabler of Volkswagen's world-leading target to produce carbon neutral EVs, including all raw materials in the battery supply chain," said Vulcan Energy Resource Managing Director Francis Wedin.

To secure low-carbon lithium for its Alfa Romeo, Fiat, Maserati, Opel, Peugeot, and its other European brands, Stellantis has agreed to purchase up to 99,000 metric tons of Vulcan's Zero Carbon Lithium over 10 years.

In addition, Stellantis is investing 50 million euros (US$52.7 million) into Vulcan, which will make the automaker the second-largest shareholder of the Australia-based lithium and energy company.

"Making this highly strategic investment in a leading lithium company will help us create a resilient and sustainable value chain for our European electric vehicle battery production," said Stellantis CEO Carlos Tavares.

"It is encouraging to see a leading automaker investing in local, low carbon lithium production for electric vehicles," said Wedin. "As our largest offtaker, we look forward to deepening our relationship with Stellantis as a substantial shareholder in Vulcan and our Zero Carbon Lithium business."

In the United Kingdom, Cornish Lithium Ltd. is developing environmentally sound technologies to directly extract lithium from its United Downs project in the United Kingdom's Cornwall region.

This, along with the company's Trelavour hardrock lithium project also in the Cornwall region, has attracted the attention of TechMet Ltd., a company founded in 2017 by South African mining magnate Brian Menell to develop assets that produce metals for which global demand is expected to vastly outweigh supply as the world moves to clean energy technologies.

Toward this objective, TechMet has agreed to invest up to US$24 million into Cornish Lithium, including an initial US$12 million investment in shares of the company.

"We have been extremely impressed by the innovative and talented Cornish Lithium team, which has made considerable progress over the past few years," said Menell, chairman and CEO of TechMet. "We are excited to be supporting the next phase of development and building a long-term partnership with Cornish Lithium, which could become a cornerstone of the UK's battery metal supply chain as well as having very positive implications for Cornwall's local economy."

STATEVOLT

Rendering of Statevolt's lithium-ion battery plant in Imperial Valley, California.

Headwinds for Piedmont

While geothermal as a low-cost and low-carbon source of lithium has attracted a lot of attention over the past year, traditional brine and hardrock mines currently dominate global lithium production.

While the U.S. has plentiful supplies of both, there are no hardrock mines and only one brine operation currently producing domestic lithium at commercial scale.

Looking for domestic sources of lithium for its American gigafactories, Tesla cut a deal last year to buy future lithium from Piedmont Lithium Ltd.'s project in North Carolina, a U.S. state that once supplied most of the world's lithium and remains rich in the battery metal.

According to a 2021 calculation, Piedmont's North Carolina project hosts 18.3 million metric tons of proven and probable reserves averaging 1.1% (422,000 metric tons) lithium oxide.

Piedmont envisions its coming North Carolina mine and processing facility will produce 30,000 metric tons of battery-grade lithium hydroxide per year.

The company's plans to produce battery-grade lithium in North Carolina have run into local opposition that has delayed development.

Piedmont's first lithium hydroxide output, however, is expected to come from its recently announced second U.S. lithium hydroxide facility that will process lithium from other sources. The company is currently advancing lithium mine projects in Quebec and Ghana

in partnerships with Sayona Mining and Atlantic Lithium, respectively.

Piedmont Lithium President and CEO Keith Phillips says that by removing the headwinds involved with also permitting a mine, the timeline for the alternate lithium hydroxide facility is expected to be much shorter.

"We think this should be funded and in construction by early next year and production by the end of 2024 or early 2025," he said.

Silver State lithium

With uncertainty as to when Piedmont's lithium hydroxide producing plans will come to fruition, Tesla and other North American EV manufacturers are looking to Nevada as a potential lithium source.

Currently, Albemarle Corp.'s Silver Peak Mine in the Silver State is the only large-scale lithium producer in North America.

Not a mine in the traditional sense, Albemarle pumps brine from Nevada's Clayton Valley basin into ponds where the water is evaporated off to produce a lithium concentrate.

Last year, Albemarle announced that it is investing upwards of US$50 million to double Silver Peak production capacity to 10,000 metric tons of lithium-carbonate-equivalent per year.

"This investment in domestic capacity shows that we are committed to looking at the many ways in which Silver Peak can provide domestic support for the growing EV market," said Eric Norris, Albemarle's president for lithium.

The evaporation ponds such as those at Silver Peak cover thousands of acres, and it takes between 12 to 18 months of evaporation to produce concentrates that can be refined into battery-grade lithium.

There are others, however, that are developing innovative technologies capable of producing the enormous quantities of lithium needed from Nevada brines much faster and with a much smaller footprint.

This includes a partnership between energy powerhouses Schlumberger and Panasonic to validate and optimize differentiated direct lithium extraction technology.

Schlumberger, best known for delivering technological solutions to the oil and gas sector, recently formed Schlumberger New Energy, a division focused on low-carbon and carbon-neutral energy technologies.

The lithium brine business, which involves drilling wells to extract the brine, is a perfect fit for leveraging Schlumberger's century of experience in oil and gas drilling and reservoir management.

One of Schlumberger New Energy's first projects in the United States is NeoLith Energy, a venture to utilize direct extraction to produce battery-grade lithium from brines in Nevada's Clayton Valley.

"We are committed to expanding the global supply chain for advanced lithium compounds to support the forecasted surge in demand and enable new opportunities for lithium production globally," said Schlumberger New Energy Executive Vice President Ashok Belani.

This project is benefitting from the lithium-ion battery experience brought by Panasonic, which joined the project in 2021

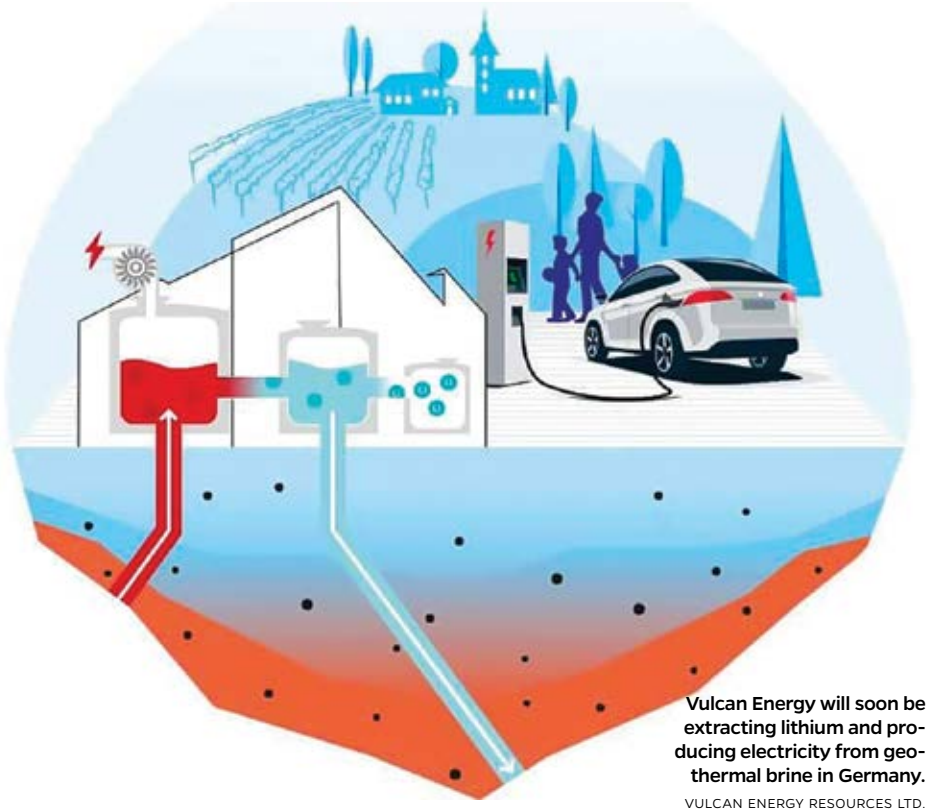
"Panasonic has a longstanding commitment to contributing to society and increasing sustainability in the supply chain as we work to produce the world's safest, highest quality and most affordable batteries is a critical priority," said Panasonic Energy of North America President Allan Swan.

Similar to Hell's Kitchen, without the added benefit of geothermal energy, NeoLith Energy plans to pump brine from the subsurface, extract greater than 90% of the dissolved lithium, and pump more than 85% of the brine back to the subsurface in an environmentally safe manner.

This cutting-edge technology is expected to result in a sustainable process for producing battery-grade lithium material at a much faster rate than the months of waiting for the sun to evaporate the water off a lithium-rich brine.

With a much smaller groundwater and physical footprint than lithium brine extraction, this process has the potential to be a game-changer that creates new market opportunities for the lithium extraction and battery manufacturing sectors and maximizes the value of the lithium-rich resource base in Nevada.

The NeoLith Energy lithium pilot plant also happens to be only 200 miles from the Tesla Gigafactory Nevada, where the growing demand for this critical EV battery metal began. DMN



Vulcan Energy will soon be extracting lithium and producing electricity from geothermal brine in Germany.
VULCAN ENERGY RESOURCES LTD.

>> *"Lithium is critical to battery production today and will only become more important as consumer adoption of EVs increases, and we accelerate towards our all-electric future."*

–General Motors Executive Vice President Doug Parks

Boxes of core from drilling at that Giga Metals' Turnagain nickel-cobalt mine project in Northern British Columbia.
GIGA METALS CORP.

More low-carbon nickel the plea for 2022

Tesla and others clamor for suppliers with low CO2 footprint

By SHANE LASLEY
DATA MINE NORTH

TESLA CEO ELON MUSK'S 2020 appeal to "please mine more nickel" served as a rallying cry for mining companies with projects positioned to deliver this critical battery metal into global markets. Going into 2022, however, the electric vehicle trailblazer's words were echoing in nearly empty warehouses as the lithium-ion batteries that power EVs are demanding more nickel than global miners can supply.

This supply-demand imbalance set the stage for an unprecedented series of events that sent nickel prices rocketing more than 250% over the course of two days in March to a brief altitude above US$100,000 per metric ton, or US$45 per pound.

This prompted the London Metal Exchange to halt nickel trading for more than a week to deal with the aftermath of the largest move in the price of a metal in LME's 145-year history.

While nickel prices settled down to somewhat normal levels after LME trading resumed, the shutdown shined a spotlight on the fact that the nickel market dynamics have shifted. As a metal primarily used as an ingredient in stainless steel and other alloys, nickel markets were more like the tides being moved by the pull of demand and the gravity of supply. Battery demand, however, has created tsunamic demand that LME was not prepared to deal with.

"They are very good at markets that are growing 5% per year or a bit more than that but when you have sudden changes in demand, which for the battery supply chain is upwards of 20% CAGR (compound annual growth rate) for the next decade, it becomes

challenging for the exchange structure to deal with that kind of growth rates," Benchmark Mineral Intelligence Chief Data Officer Caspar Rawles told Data Mine North.

Musk's appeal to mine more of this metal reflects a growing concern that the global transition to EVs and the lithium batteries that power them will outpace the mining sector's ability to deliver new supplies of this metal traditionally used for stainless steel and other alloys.

In a scenario where global governments and industries achieve the 2-degree Celsius temperature increase limit outlined in the 2015 Paris Agreement, the International Energy Agency estimates that the EV and low-carbon energy sectors will need as much as 3.8 million metric tons of nickel per year by 2040.

At this rate of EV and clean energy adoption, IEA forecasts that global nickel demand for all sectors will hit 6.3 million metric tons by 2040, which is well more than double the 2.7 million metric tons produced worldwide in 2021.

This explosive demand for an element vital to global EV and green energy aspirations prompted the U.S. Geological Survey to add nickel to the 2022 list of minerals and metals critical to America.

Nickel miners, however, have been able to scale up production to meet the immediate demands of the burgeoning EV revolution. This quick response, coupled with recession concerns, has weighed on the price of nickel. By mid-year, nickel had dropped to around US$10/lb, which is where it was at going into 2022.

Low-carbon Nickel West

With competition for nickel expected to be fierce over the next two decades, global automakers and battery manufacturers have been cutting deals to secure ample supplies of this increasingly critical metal – the lower the carbon dioxide footprint, the better.

These deals range from contracts with some of the largest miners on the planet to agreements with junior mining companies with aspirations to deliver their first nickel into markets in the next few years.

Tesla has agreements across this entire spectrum, including a contract to buy low-carbon nickel from BHP's expanding Nickel West project in Australia.

"BHP produces some of the lowest carbon intensity nickel in the world, and we are on the pathway to net-zero at our operations," said BHP Minerals Australia President Edgar Basto. "Sustainable, reliable production of quality nickel will be essential to meeting demand from sustainable energy producers like Tesla Inc."

Under a mid-2021 agreement, the Anglo-Australian mining giant is supplying the electric automaker with an estimated 18,000 metric tons of this battery metal from Nickel West, a Western Australia operation that mines, refines, and then produces battery-grade nickel sulfate.

In addition to the nickel supply pact, BHP and Tesla have joined in a battery sustainability partnership that uses blockchain to trace raw materials from mines to EVs; exchanges technical information on battery raw materials production; and promotes the importance of sustainability in the resources sector, including identifying partners who are most aligned with BHP and Tesla's battery supply chain values.

"This is an alliance that will promote sustainability in the mining and resources sector," said Samantha Langley, principal of business development at BHP.

BHP and Tesla are also working together to identify opportunities to lower carbon emissions in their respective operations through increased use of renewable energy paired with battery storage.

"We are at the beginning of a revolution that will transform our world," Langley added.

Toyota Motor Corp. and Panasonic Corp. have also signed an agreement to acquire nickel sulfate from BHP's Nickel West operation.

The supply of nickel sulfate from Nickel West is expected to enable Prime Planet Energy & Solutions, a joint venture between Toyota and Panasonic, to develop batteries with a low-carbon footprint that will be supplied to EV manufacturers, including Toyota.

"I am delighted that we share the same values and have taken initiatives as 'one team' towards realizing a carbon-free green society," said Prime Planet Energy & Solutions President and CEO Hiroaki Koda. "We will work towards optimizing the overlapping value chains to be more competitive and to continuously improve efficiency in our related operations."

BHP

Canadian nickel from Vale

Tesla has also secured responsibly mined and refined Canadian nickel for its North American lithium battery gigafactories.

In May, Vale confirmed that Tesla had entered into a long-term contract to buy low-carbon nickel from the Brazilian miner's mines and refineries in Canada.

Much like BHP's Nickel West operation in Australia, Vale's Voisey's Bay mine and Long Harbour refinery in Newfoundland and Labrador, Sudbury operations in Ontario, and the Thompson mine in Manitoba produce some of the lowest-carbon nickel in the world.

The low-carbon footprint of Vale's Canadian nickel operations is due to the nickel sulfide ore at these mines requiring less energy to convert to battery-grade nickel sulfate than laterite ores that are the source of much of the world's nickel, and the abundance of hydropower delivered to the mines and refineries.

The lowered CO2 emissions from these operations makes the nickel Vale is producing in Canada attractive to Tesla and other EV manufacturers that want to minimize the CO2 emissions to manufacture vehicles meant to prevent additional greenhouse gasses from entering the atmosphere.

"We are pleased to have the leading electric vehicle manufacturer Tesla among our customers," said Vale Executive Vice President of Base Metals Deshnee Naidoo. "This agreement reflects a shared commitment to sustainability and shows very clearly we are the supplier-of-choice for low-carbon and high purity nickel products essential for long-range batteries."

BHP

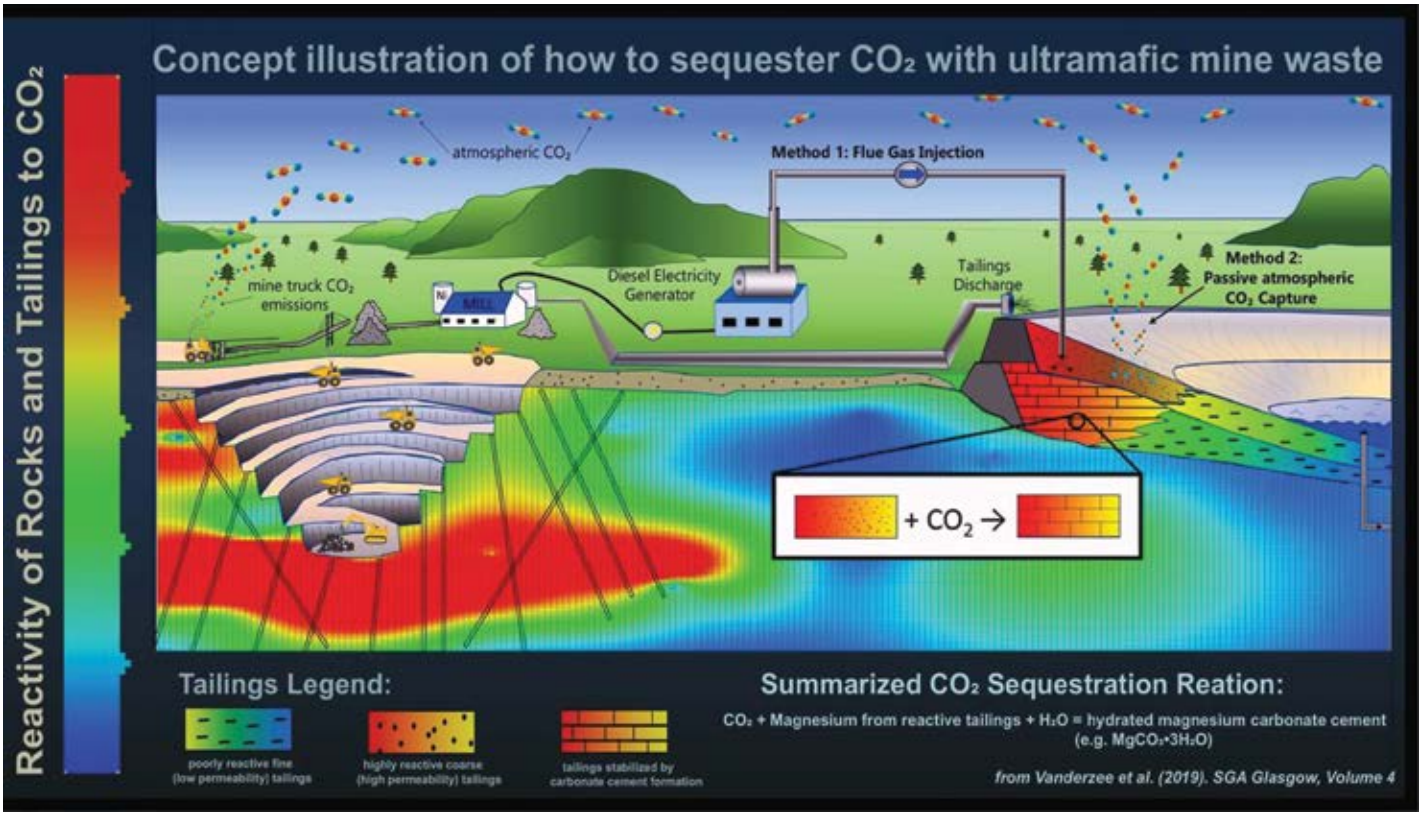
Above: BHP'S Nickel West operation at dusk.
Left: Battery-grade nickel sulfate produced at BHP's Nickel West operation in Australia.

CO2 absorbing US mine

While expanding current operations is the quickest and most effective means of scaling up global nickel supplies to keep pace with the EVs rolling off assembly lines, the rapid development of new nickel mines will also be required to fill the more than doubling of demand forecast in the coming two decades.

During Tesla Battery Day 2020, Musk famously said, "Tesla will give you a giant contract for a long period of time if you mine nickel efficiently and in an environmentally sensitive way. So, hopefully, this message goes out to all mining companies – please get nickel."

Talon Metals Corp. and Rio Tinto got the message and are jointly advancing toward the development of a mine in Minnesota that not only produces nickel and copper but also turns atmospheric CO2 into rock that can be stored for geological time periods – checking off several of the environmental, social, and governance



STERLING VANDERZEE

(ESG) boxes of EV manufacturers seeking sustainable sources of battery metals.

This is one of the reasons why Tesla cut a deal to purchase 165 million lb of nickel in concentrate from Tamarack over six years, once the nickel mine goes into production.

The agreement is conditional upon Talon earning a 60% interest in Tamarack from Rio Tinto. Talon, which earned a 51% interest in the project last year, can increase its ownership to 60% through the completion of a feasibility study that details the proposed mine, and paying Rio Tinto US$10 million.

Talon has committed to making every reasonable effort to be producing nickel at Tamarack by the end of 2025. This deadline could be extended by a year before Tesla has the right to look elsewhere for nickel to go into the lithium-ion batteries powering its EVs.

In the meantime, Tesla will work with Talon to optimize nickel concentrate grades and metal recoveries. The parties have also agreed to share in any additional economics derived from byproducts such as cobalt.

"This agreement is the start of an innovative partnership between Tesla and Talon for the responsible production of battery materials directly from the mine to the battery cathode," said Talon Metals CEO Henri van Rooyen. "Talon is committed to meeting the highest standards of responsible production that is fully traceable and that has the lowest embedded CO2 footprint in the industry."

A Carbfix for Tamarack

Carbfix, an Icelandic company involved with developing the carbon-storing technology that promises to shrink the CO2 footprint at Tamarack, was recently awarded $1 million from the XPRIZE contest backed by Musk.

A global future-positive movement supported by the Musk Foundation, XPRIZE provides cash awards to individuals, teams, and organizations that compete for the best ideas to tackle global challenges.

On the environmental front, the Musk Foundation is supporting the XPRIZE for Carbon Removal, with $100 million being awarded to teams with technologies that demonstrate the viability of economically removing billions of tons of CO2 from the atmosphere.

"The ultimate goal is scalable carbon extraction technologies that are measured based on the 'fully considered cost per ton' which includes the environmental impact," Musk said at the launch of XPRIZE for Carbon Removal. "This is not a theoretical competition; we want teams that will build real systems that can make a measurable impact and scale to a gigaton level."

Carbfix was one of 15 teams that were awarded $1 million to further advance their CO2 capturing technologies as they compete for the $80 million in grand prizes to be awarded in 2025.

"We've already been applying our method of underground CO2 mineralization for 10 years," said Carbfix CEO Edda Sif Pind Aradóttir. "Presently, we are aiming for significant upscaling of our tried and tested technology, an ambition which will be greatly supported by our XPRIZE success and our excellent partnerships in those projects."

Carbfix' tried and tested technology involves dissolving atmospheric CO2 in water and then injecting this sparkling mineral water into favorable rock formations to form solid carbonate minerals – a sort of antimining process that removes an element from the atmosphere and turns it into a mineral deposit in the lithosphere.

The potential to mimic this process at Tamarack drew Tesla's attention.

"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.

The Carbfix solution has also attracted the attention of the U.S. Department of Energy, which is investing $2.2 million to study the potential of applying this technology at Tamarack.

This type of carbon-capturing technology could make the minerals produced more attractive to electric automakers.

"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," said Baglino.

CO2 absorbing nickel projects in BC

Carbfix is not the only XPRIZE-winning company that is developing technologies to store CO2 at nickel mines, and Tamarack is not the only North American operation with the potential to turn CO2 to stone while also producing battery metals.

Carbin Minerals, a Canadian company founded by University of British Columbia Professor Greg Dipple, is developing a technology that directly sponges CO2 out of the atmosphere into the tailings left behind from mining nickel, cobalt, and other metals.

This idea of locking up CO2 in this waste from mines that produce metals needed for the low-carbon future is not new to Dipple, who has been working on this technology with a team at UBC for 15 years.

The professor realized that ultramafic rocks – igneous rock with a high magnesium and iron content – are among the largest CO2 storing reservoirs on Earth. The carbon-absorbing potential of these rocks, however, is limited when they are buried away from the atmosphere.

It so happens that rich stores of nickel and cobalt are also found in ultramafic rocks. The mining and grinding of these rocks to a sand-like consistency to recover the lithium-ion battery metals maximizes the carbon sequestering potential of the rocks.

Tests recently carried out by Dipple and his team at UBC indicate that Giga Metals Corp.'s Turnagain project in Northern British Columbia could one day be home to such a greenhouse gas-absorbing mine.

A 2020 preliminary economic assessment outlines plans for a mine at Turnagain that could produce 33,215 metric tons of the nickel and 1,962 metric tons of the cobalt needed for EV batteries annually for 37 years.

The tailings left behind after recovering the battery metals at Turnagain are also really good at absorbing CO2 out of the atmosphere.

An initial four-week test carried out by Dipple showed a mine at Turnagain could absorb nearly as much CO2 from the atmosphere as is expected to be emitted per metric ton of nickel if an electric mining fleet was used to do the digging and hauling.

Dipple's testing indicates that these CO2 absorption rates would be higher under actual mining scenarios.

"During periods of optimal moisture and mixing, the sequestration rates increased up to three times the long-term average," he said.

The testing also showed that only about 10% of the brucite – a magnesium hydroxide mineral in ultramafic rocks at Turnagain that is responsible for sponging atmospheric CO2 – was consumed during the one-month sequestration test, indicating that Turnagain mine tailings would absorb more of the greenhouse gas with longer exposure.

Testing by Dipple also found that FPX Nickel Corp.'s Baptiste project in central BC has the potential to absorb more CO2 from the atmosphere than would be emitted to mine the nickel mined there.

A road-accessible project only about three miles (five kilometers) from rail and about 50 miles (80 kilometers) northwest of Fort St. James, BC, Baptiste hosts 5.37 billion pounds of nickel in 2 billion metric tons of indicated resource averaging 0.122% nickel.

A 2020 PEA outlines plans for a mine that would produce an average of 99 million lb of nickel annually over 35 years.

Testing by Dipple's team shows that direct injection of flue gas into the tailings could absorb up to 7.3 to 8.4 grams of CO2 per kilogram of material.

"These new results were achieved using representative tailings material generated from the 2021 metallurgical testing pilot plant program, highlighting our interest in moving beyond idealized experimental conditions to advance the scientific understanding of carbon mineralization in a practical, real-world context," said FPX Nickel President and CEO Martin Turenne.

FPX is carrying out two larger-scale tests – a six-month experiment on roughly 2.4 metric tons of Baptiste tailings material and a one-year test on approximately 300 kilograms of tailings material, designed to better understand the longer-term carbon sequestration potential of undisturbed tailings in the project region. DMN

Electra Battery Materials cobalt refinery in Ontario, Canada.
ELECTRA BATTERY MATERIALS CORP.

Critical cobalt overshadowed by lithium

Replacing oft maligned metal in EV batteries comes at a cost

By SHANE LASLEY
DATA MINE NORTH

TRADITIONALLY A HEADLINE GRABBING metal due to the perceived human rights and monetary costs it adds to lithium-ion batteries and the electric vehicles they power, cobalt is being overshadowed by the enormous demand and price increases for the lithium and nickel that also go into the storage cells that deliver the "E" to the EV revolution.

Cobalt, however, continues to be a vital ingredient that improves the energy density and longevity of EV batteries.

"Future facing commodities like cobalt play a pivotal role in decarbonizing energy consumption and the electric vehicle revolution," said Ash Lazenby, U.S. cobalt marketer and trader at Glencore. "Glencore is already a leading producer, recycler and supplier of these commodities, which underpin our own ambition of achieving net zero total emissions by 2050."

Cobalt miners such as BHP have thus far been able to keep pace with the growing demand for this future facing battery metal.

Late last year, S&P Global Market Intelligence forecast that the cobalt market would move into surplus in 2022 after suffering an estimated shortage of 1,800 metric tons in 2021.

More than 70% of the world's cobalt, however, comes from mines in the Democratic Republic of Congo (DRC), a country plagued with political and social issues. This puts the supply of this critical battery metal at risk of disruptions from civil unrest.

As it turns out, natural disasters are also a risk tolled by placing this much global cobalt supply in one basket. In April, heavy flooding in South Africa washed away infrastructure that is used to deliver cobalt mined in DRC to ports and then onward to global markets.

This situation forced Glencore, the world's largest cobalt producer, to invoke force majeure due to the inability to fulfill its contractual commitments for cobalt from its DRC operations. This disruption could motivate battery and automakers to put further effort into implementing battery chemistries that reduce the amount of cobalt needed – a task that is not easy without sacrificing the safety and performance provided by this critical transition metal.

At the same time, governments and mining companies are advancing projects that will diversify the supply chain and lower the risk of supply disruptions for this critical battery metal.

Changing the recipe

While flooding that prevented much of the global supply of cobalt from leaving Africa adds to EV manufacturers' desire to lessen the amount of this metal going into lithium-ion batteries and look for alternative sources, the headline grabbing human rights conditions in DRC was the original impetus for these moves.

Artisanal mining in DRC has been condemned by human rights advocates due to the unsafe working conditions for the men, women, and children digging into some of the richest sources of cobalt on Earth.

It is estimated that artisanal mines, a term given to small family-scale mining operations that typically involve hand digging to extract the desired mineral, are the source of 10 to 20% of the cobalt coming out of DRC, or roughly seven to 14% of global supply.

Perceptions that the cobalt going into a battery may have been dug up by a child working in unsafe conditions is a problem for EV and green energy companies seeking to demonstrate the highest levels of environmental, social, and governance (ESG) standards.

Bending to pressure from human rights groups and socially conscious EV drivers, many electric automakers and lithium-ion battery manufacturers have sworn against sourcing their cobalt from DRC – especially artisanal mines.

The perception that cobalt could be tainted by DRC human rights abuses has automobile and battery manufacturers looking for solutions, including less cobalt-intensive recipes for cathodes.

Tesla, which delivered nearly 1 million EVs to customers during 2021, is among the companies seeking lithium-ion battery chemistries that require less cobalt.

Eliminating cobalt from the lithium-ion batteries, however, is akin to developing a gluten-free pizza crust recipe – alternatives are available for those who absolutely cannot have gluten, but it is tough to develop a flourless recipe that has all the attributes that would make all pizza lovers want to eat the pie.

While other transition metals such as manganese, nickel, iron, and titanium are potential substitutes in a lithium-ion battery recipe, none can match cobalt when it comes to delivering high-voltage, energy density, and the movement of lithium ions.

"Moving away from high cobalt content means the new cathode materials must be optimized for all of these performance characteristics via subtle changes in the arrangement of the transition metals and their relative compositions," the U.S. Department of Energy explains.

Responsibly sourced cobalt

While government and industry efforts are expected to lower the percentage of cobalt going into each battery, this will not offset the massive volume of batteries to be produced over the coming years and decades. This has EV manufacturers, even those looking to eliminate cobalt from batteries altogether, racing to the mines to ensure they have the socially and environmentally responsible supplies of this battery metal.

Tesla, General Motors, and BMW are among the automakers that have cut deals for responsibly-sourced cobalt for the batteries going into their EVS.

In April, GM struck a multi-year agreement to purchase cobalt from Glencore's Murrin Murrin operation in Western Australia,

ADOBE STOCK

Cobalt sulfate is unmatched when it comes to delivering high-voltage, energy density, and allowing for the movement of lithium ions in batteries.

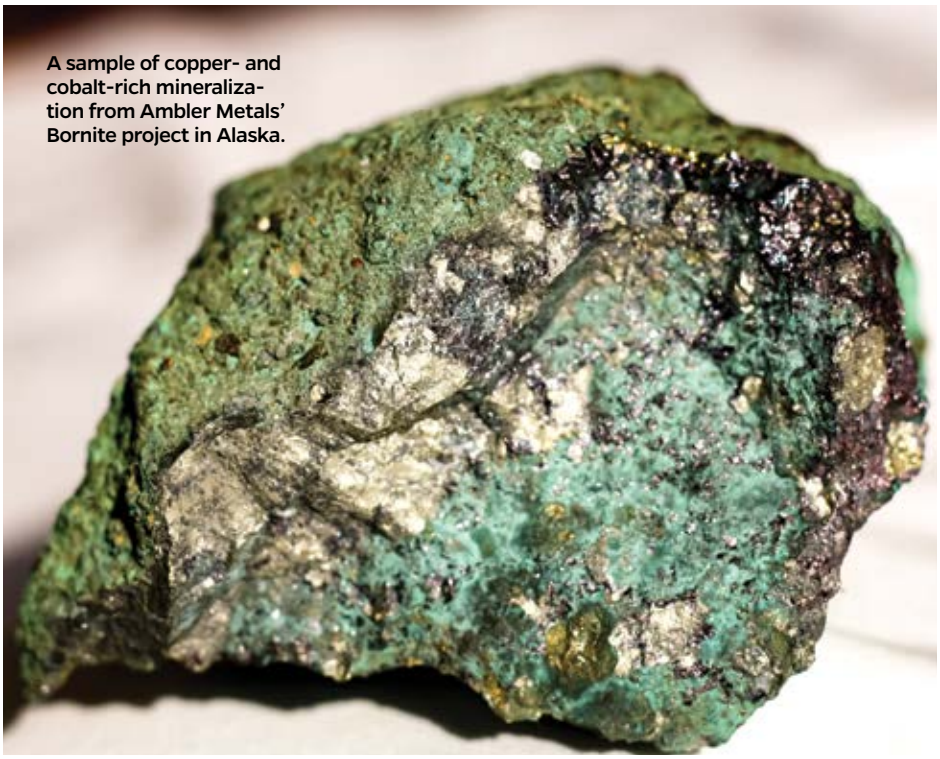
which sidesteps any controversy related to whether the battery metal came from an artisanal mine in DRC.

Both Glencore and GM are also members of the Responsible Minerals Initiative, a group of 400 companies and organizations dedicated to ensuring mineral supply chains contribute positively to social-economic development globally.

"GM and our suppliers are building an EV ecosystem that is focused on sourcing critical raw materials in a secure sustainable manner," said Jeff Morrison, vice president of global purchasing and supply chain at GM. "Importantly, given the critical role of EVs in reducing the carbon footprint of the transportation sector, this agreement is aligned with our approach to responsible sourcing and supply chain management."

For GM and other North American EV manufacturers seeking to establish secure and sustainable supply chains, sourcing cobalt in the U.S. and Canada would be ideal.

While the U.S. and Canada only produced 5,000 metric tons of cobalt during 2021, which accounted for about 3% of global production, both countries have cobalt-enriched areas that could provide North American supplies.



A sample of copper- and cobalt-rich mineralization from Ambler Metals' Bornite project in Alaska.

SHANE LASLEY

Cobalt is great place to look

When looking around for a potential North American source of cobalt, a town in a mining jurisdiction like Ontario that brandishes the name of this critical battery ingredient is a great place to start.

This aptly named town about 260 miles north of Toronto is known for the rich stores of silver-cobalt mineralization historically produced there.

While this region still has the potential to feed cobalt into lithium battery supply chains, bringing a cobalt refinery that operated there from 1996 to 2015 out of retirement is considered a first priority.

Toward this goal, the provincial government has invested C$5 million to help support Electra Battery Materials Corp.'s efforts to upgrade and expand this refinery to deliver battery-grade cobalt into North American supply chains.

Since acquiring the refinery, Electra has been advancing a strategy to develop an eco-industrial park around the hydrometallurgical facility that is capable of supplying enough battery materials for 1.5 million electric vehicles per year.

Toward this objective, Electra is upgrading and expanding the existing refinery to produce 25,000 metric tons of battery-grade cobalt sulfate annually, which will account for more than 25% of this important lithium-ion battery ingredient produced outside of China.

In parallel, a circuit is being built alongside the cobalt refinery that will recycle lithium, nickel, cobalt, copper, and graphite from spent lithium-ion batteries. Electra also plans to add a plant to produce nickel sulfate, another key lithium battery ingredient, during later phases of development at the park.

This would make the Electra Battery Materials Park – which lies within 500 of Detroit, Michigan – a major hub for supplying battery-grade cobalt, nickel, lithium, and graphite needed for EV manufacturing facilities being built in Canada and the U.S.

Electra also owns more than 10,000 hectares (24,700 acres) of silver-cobalt exploration properties along the Ontario Cobalt Belt near the emerging battery park, which could offer new sources of cobalt coming out of the critical minerals-enriched province.

In addition to its Ontario initiatives, Electra is in talks with the Quebec government to build a cobalt refinery in a battery materials park being developed near the town of Becancour, a region that has quickly earned the name Battery Valley.

General Motors, POSCO Chemical, and BASF are among the global-scale corporations developing battery materials and recycling plants in this strategic Quebec locale.

Now, Electra has entered into preliminary talks with Quebec officials to build a cobalt refinery in Battery Valley.

"Given a forecasted deficit in domestic cobalt sulfate production by 2025, we have received significant interest from industry and government stakeholders to build a second refinery in North America," said Electra Battery Materials CEO Trent Mell. "The industrial park in Bécancour, Quebec is quickly becoming an important future hub for EV battery materials in North America given its numerous advantages, including a deep-water port, extensive infrastructure, hydro-electric power, strong support from the Quebec government, and a qualified work force."

An Idaho alternative to DRC

In the U.S., Electra is advancing exploration on its Iron Creek cobalt-copper project in Idaho, which hosts one of the few primary cobalt deposits in the world.

"At a time of heightened geopolitical tensions, America must commit to securing a domestic supply of critical minerals for the green energy transition," said Mell. "Idaho is arguably the most prospective location in the world to identify new

primary sources of cobalt outside the DRC."

According to a 2019 calculation, Iron Creek hosts 2.2 million metric tons of indicated resource averaging 0.26% (12.3 million pounds) cobalt and 0.61% (29 million lb) copper; plus 2.7 million metric tons of inferred resource averaging 0.22% (12.7 million lb) cobalt and 0.68% (40 million lb) copper.

In March, Electra announced that broad widths of strong copper-gold mineralization tapped with drilling extends the higher-grade cobalt mineralization at Iron Creek. A mine at this high-grade and growing cobalt deposit could provide a North American source for Electra's refinery.

"Electra's ultra low carbon refinery in Canada will create the first domestic supply of battery grade cobalt for EVs later this year and Idaho can become an important part of a continental onshoring strategy that is both in the national interest and good for the environment," said Mell.

Intriguing coproduct

In addition to Ontario and Idaho, several North American exploration projects have the potential to offer cobalt as a coproduct of other metals that would be produced if a mine were to be developed.

One of the most intriguing of these deposits is at Fortune Minerals Ltd.'s NICO cobalt-gold-bismuth-copper project in Northwest Territories.

According to a 2020 plan, a mine at NICO and an associated refinery would produce an average of 1,800 metric tons of battery-grade cobalt sulfate; 1,700 metric tons of bismuth; 300 metric tons of copper; and 47,000 oz of gold annually over the first 14 years of mining.

In January, Fortune entered into a deal to acquire a former steel fabrication plant in Alberta to build a refinery to process concentrates produced at NICO.

"Cobalt, lithium and nickel are all minerals with huge demand in the modern world. Fortune's new refinery is exactly the type of job creating, diversifying investment we envisioned with our mineral strategy and action plan," said Alberta Premier Jason Kenney.

Giga Metals Corp.'s Turnagain project in British Columbia is another potential Canadian source of cobalt, which would be produced along with nickel, another important material in lithium-ion batteries.

A 2020 study outlines plans for a mine at Turnagain that would produce an average of 33,215 metric tons of nickel and 1,962 metric tons of cobalt annually over 37 years of mining.

It just so happens that the tailings left behind after the nickel and cobalt extracted from the ore at Turnagain are really good at absorbing carbon dioxide out of the atmosphere.

Testing carried out by University of British Columbia Professor Greg Dipple showed a mine at Turnagain has the potential to offset nearly all the CO2 if an electric mining fleet charged with Northern BC hydropower was used to do the digging and hauling.

In Alaska, a world-class copper deposit being advanced toward development by Ambler Metals, a joint venture owned equally by Trilogy Metals Inc. and South32 Ltd., has the potential to produce cobalt alongside the copper needed in vast quantities for EVs and renewable energy.

According to a 2022 calculation, Bornite hosts 6.3 billion lb of copper and 88 million lb of cobalt.

Metallurgical work shows promise that a cobalt concentrate could be produced at this world-class Alaska deposit, which is a good indication that a future mine there could produce the battery metal as a byproduct.

While such cobalt byproducts have often not been economical to pursue in the past, the rising demand and prices of a metal that is hard to replace in the lithium battery recipes will likely make such endeavors an intriguing option to boost and diversify cobalt supplies. PMN

Miners working underground at Electra Battery Materials' Iron Creek cobalt-copper project in Idaho.

ELECTRA BATTERY MATERIALS CORP.

Elon Musk says an NMC battery cathode made with two-thirds nickel and one-third manganese would allow Tesla to make 50% more lithium battery cells with the same amount of nickel.

ADOBE STOCK

More manganese equals more EV batteries

Manganese-rich cathode recipes may stretch other ingredients

By SHANE LASLEY

DATA MINE NORTH

WHILE NOT AS TALKED ABOUT as other battery ingredients such as cobalt, lithium, and nickel, manganese is an important stabilizing ingredient in the cathodes of the nickel-manganese-cobalt lithium-ion batteries widely used in electric vehicles and electronics.

"Their composition helps determine how long you can talk on the phone, how far you can drive an electric car, how fast a battery can recharge and how much energy you can store from your solar panels," Umicore, a global materials technology and recycling group, wrote on NMC cathode material. "The manganese in the cathode material has an important impact on the safety of the battery cells and safety is a main priority when it comes to batteries that power electric cars and electric devices."

Despite manganese's importance to the lithium-ion batteries needed to power the EV revolution and store renewable energy, there are currently no mines producing this critical battery metal in the United States or Canada. As a result, North American manufacturers must rely on imports from Gabon, South Africa, Australia, Georgia, and other countries for their manganese needs.

Two companies, however, are looking to fill the growing demand for manganese from North American sources – one from an old iron mine in New Brunswick and the other from a strategic stockpile in the Arizona desert.

"Interesting potential"

While lithium-ion batteries are powering enormous new demand for manganese, steel and other alloys remain the dominant use for this critical metal.

According to the United States Geological Survey, an estimated 640 metric tons of manganese were used for steelmaking, batteries, and other applications in the U.S. during 2021.

"Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys," the USGS inked in its Mineral Commodity Summaries 2022 report. "Additional quantities of ore were used for nonmetallurgical purposes such as in the production of animal feed, brick colorant, dry cell batteries, and fertilizers."

Globally, there were 20,000 metric tons of manganese mined last year – South Africa, Gabon, and China accounted for roughly 78% of this total.

This puts manganese slightly into oversupply, which is why it has not captured headline attention. This abundance also makes it a perfect metal to substitute for other lithium battery cathode metals with tighter supply.

Tesla and VW are among the companies that are considering more manganese-rich recipes to ensure there are enough batteries to meet the ambitious EV sales targets.

"It is relatively straightforward to do a cathode that's two-third nickel and one-third manganese, which will allow us to make 50% more cell volume with the same amount of nickel," Tesla CEO Elon Musk said during the company's Battery Day 2020 event.

He reiterated interest in manganese as an abundant material that would be leaned on for increased battery production during the opening of Tesla Gigafactory Berlin earlier this year.

"I think there's an interesting potential for manganese," he said in response to a question about graphene batteries.

"We need tens, maybe hundreds of millions of tons, ultimately. So, the materials used to produce these batteries need to be common materials, or you can't scale," he went on to explain about the volume of raw materials it will take to reach Tesla's EV production goals.

Volkswagen is also investigating high-manganese cells because they offer "the optimum cost-benefit ratio."

While these high-manganese cells currently have some drawbacks in terms of energy density, some consider them slightly better than lithium-iron-phosphate batteries, which are currently being put into shorter-range vehicles. Using less expensive and more plentiful materials is bringing down the costs of daily commuters, saving nickel for higher-end, longer-range vehicles.

Whether high-manganese batteries catch hold or cells with just 10% manganese in the cathode, such as the popular NMC-811 battery, the sheer volume of EVs expected to hit global highways over the next decade is going to significantly push the demand for manganese higher.

Canada's Battery Hill

In a move to shorten North American lithium battery supply chains, Manganese X Energy Corp. is rapidly advancing plans to develop a manganese mine at its aptly named Battery Hill project in New Brunswick, Canada.

In May, the company published a preliminary economic assessment that outlines a financially robust mine at Battery Hill that would average 68,000 metric tons of battery-grade, high-purity manganese sulfate monohydrate (HPMSM) annually for 47 years.

This long-lived operation is based on 35.1 million metric tons of measured and indicated resources averaging 6.24% manganese and 10.94% iron; plus 27.7 million metric tons of inferred resource averaging 6.46% manganese and 10.73% iron.

Given the robust economics – an after-tax net present value (10% discount) of US$486 million and 25% internal rate of return – a mine and processing facility at Battery Hill is expected to pay back the US$350 million capital costs for its development in just 2.8 years.

"The PEA represents the most significant milestone to date for Manganese X and makes us the forerunner of becoming the first

publicly traded company in Canada and the US to commercialize high-purity electric vehicle quality compliant manganese," said Manganese X Energy CEO Martin Kepman.

Battery Hill also happens to be road accessible and only about eight miles east of the Maine border, which offers affordable access to manufacturers in both the United States and Canada that need this metal to stabilize the structure of the lithium-ion batteries powering EVs and a plethora of cordless electronics.

Traditionally, selenium has been used to create battery-grade manganese. This additive is regarded as a negative mark on the environment and the quality of the manganese. This problem has been addressed by Manganese X, which has worked with Kemetco Research Inc. to develop a process for producing battery-grade manganese without introducing selenium.

"Thanks to our proprietary extraction process, we can develop a superior quality manganese product by eliminating selenium, considered a toxic pollutant and yet utilized by some of the HPMSM producers worldwide to reduce their costs of production," Kepman added.

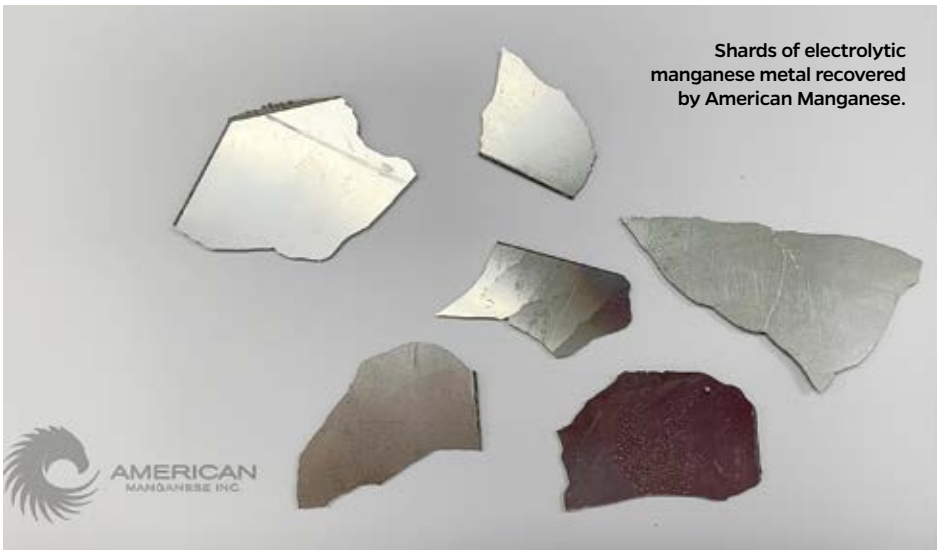
The company says it is in discussions with several potential strategic partners looking to source the high-purity manganese products that could be produced at Battery Hill.

"We have received great feedback after publishing our strong PEA," said Kepman. "Currently, there is zero manganese mining in Canada and the US. We aim to change this, and we are working diligently to facilitate a new North American production."

Because Battery Hill is the site of a former iron mine and more recent bench-scale development programs aimed at establishing a manganese operation there, Manganese X enjoys a considerable head start on delivering battery-grade manganese to the North American market.

Due to the previous developments, the site already has much of the needed infrastructure in place – security and administration buildings; crushing facility; process plant; sulfuric acid plant; truck shop and maintenance facilities; waste rock storage facilities; run-of-mine mill feed stockpile; filtered residue storage area; sediment ponds; power, water, and fuel supply.

Manganese X is having a pilot plant developed that will demonstrate its proprietary process under near commercial-scale operating conditions, using a modular design that can be scaled up to help meet the expected rapid rise in market demands for high-quality, battery-grade manganese.



Shards of electrolytic manganese metal recovered by American Manganese.

AMERICAN MANGANESE INC.

"At the current rate of EV production, a significant manganese deficit is being forecasted," said Kepman. "Our Battery Hill manganese property and its corresponding long economic life cycle will help to mitigate this deficit down the road."

Strategic U.S. stockpile

In the U.S., RecycLiCo Battery Materials Inc. (formerly American Manganese) is investigating the potential of using its patented technology developed for the recycling of lithium-ion batteries to produce electrolytic manganese metal (EMM), an important alloy in stainless steel and a precursor to battery-grade manganese, from a strategic stockpile of manganese ore in the desert near Wenden, Arizona.

Purchased by the U.S. government in the 1950s and 1960s, the Wenden Stockpile contains roughly 322,000 metric tons of material. However, this potential domestic source of manganese has been languishing in the desert for the past six decades due to the need for a specialized process to efficiently transform the low-grade ore into useful forms of advanced manganese material.

Toward the end of 2020, the U.S. Defense Logistics Agency awarded RecycLiCo a grant to investigate the viability of using its patented process to produce electrolytic manganese metal from the stockpile.

After nearly a year of sampling and bench-scale testing, RecycLiCo successfully produced electrolytic manganese metal from the material.

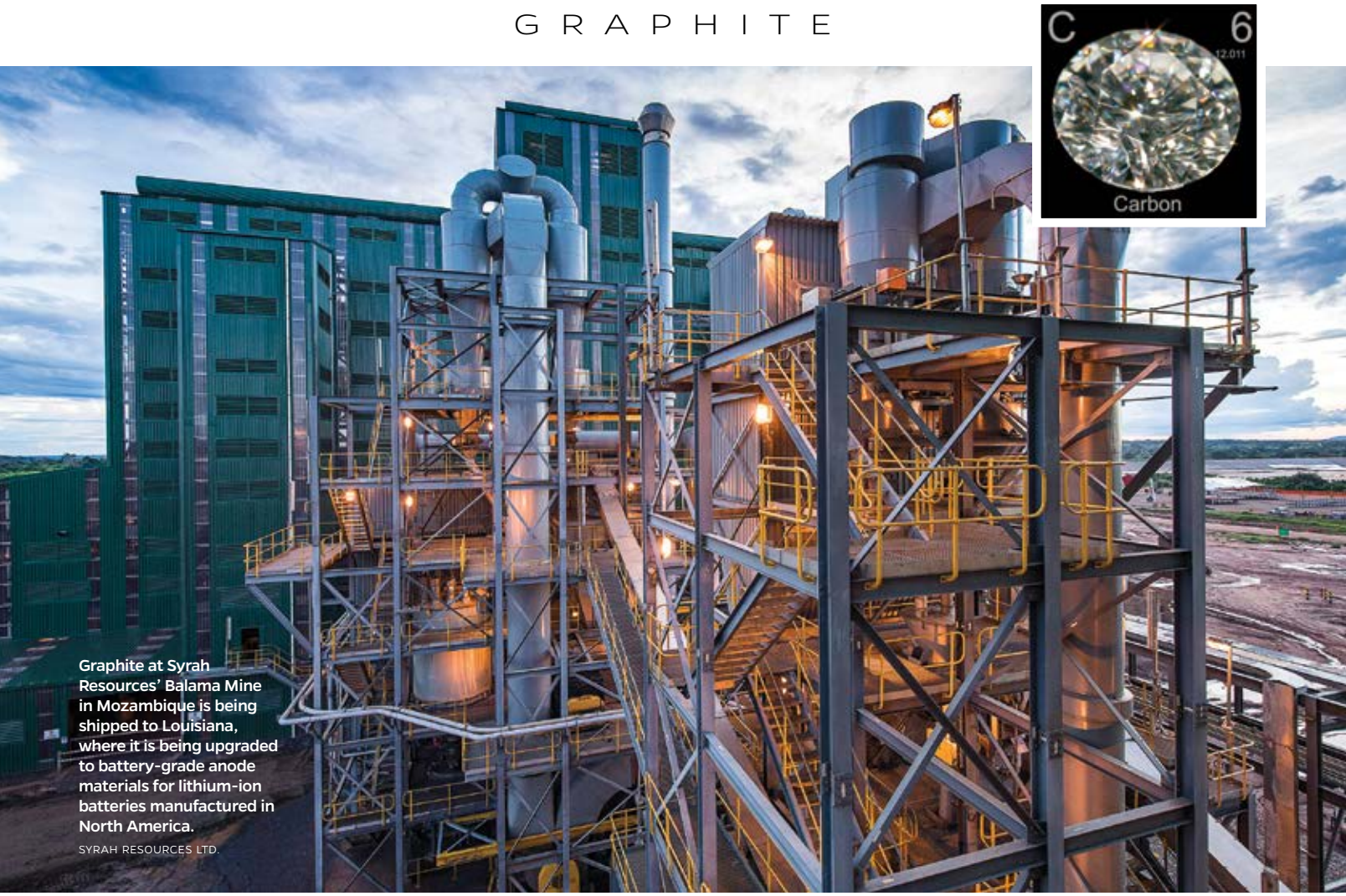
Toward the end of 2021, the company submitted its final report to the Defense Logistics Agency, signifying the completion of the Wenden Stockpile Reclamation and Advanced Material Processing project.

"The patented American Manganese process represents a significant opportunity for producing electrolytic manganese metal, electrolytic manganese dioxide, and potentially battery-grade manganese sulfate, using as feedstock the 350,000 short dry tons of National Defense Stockpile material grading about 22% manganese located just outside Wenden, Arizona," according to the report.

Congressman Paul Gosar, R-Arizona, says these findings are good news for the residents of Wenden and the American critical mineral supply chain.

"At each step in the process American Manganese has been open and transparent on their work and is presenting a solution to transform the unwanted stockpile of low-grade material, long ago paid for by the U.S. taxpayer, into modern National Defense Stockpile material," said Gosar. "The U.S. remains 100% dependent on foreign EMM and we simply cannot remain dependent on foreign supply when electrolytic manganese metal is a designated strategic defense mineral. Advancing this project is a strong first step towards securing a durable American source of supply."

Defense Logistics Agency, which oversees the U.S. National Defense Stockpile, has electrolytic manganese metal listed on its 2022 stockpile acquisitions list. DMN



Graphite at Syrah Resources' Balama Mine in Mozambique is being shipped to Louisiana, where it is being upgraded to battery-grade anode materials for lithium-ion batteries manufactured in North America.
SYRAH RESOURCES LTD.

More graphite needed for EVs – a lot more

By 2030, batteries may need 5x all the graphite mined in 2021

By SHANE LASLEY
DATA MINE NORTH

WHILE SHORTAGES OF THE LITHIUM and nickel needed for electric vehicle batteries has dominated news headlines over the past year, the massive demand for graphite has largely been overlooked. As the primary ingredient in the anode side of lithium-ion batteries, graphite is the single largest element in lithium-ion batteries and the mining sector's inability to keep pace with skyrocketing demand of this critical mineral could put the brakes on the EV revolution.

According to the global lithium-ion battery supply chain experts at Benchmark Mineral Intelligence, a megafactory capable of producing 30 gigawatt-hours of battery storage annually requires about 33,000 metric tons of graphite per year.

When you extrapolate this out over the more than 300 gigafactories that are being built or are in the pipeline, this equates to up to 9.9 million metric tons of graphite per year to feed all these lithium-ion battery plants running at full capacity. Using the 70-70 rule – a more realistic measure that 70% of these battery plants go into production running at an average of 70% design capacity – the global lithium battery sector would need about 4.9 million metric tons of graphite per year.

This correlates with S&P Global Platts' forecast that by 2030 it will take 5 million to 6 million metric tons of graphite to meet annual global demand for this critical carbon material.

This compares to only about 1 million metric tons that was mined globally to meet the demands of all industrial sectors during 2021, according to "Mineral Commodity Summaries 2022," an annual report published by the United States Geological Survey.

Ramping up graphite production by 500 to 600% over 10 years is an enormous task for global miners.

"Supply will struggle to catch up with graphite demand," said George Miller, senior price analyst at Benchmark.

Emerging NA supply chain

Currently, China dominates both the mining of graphite and upgrading this carbon material into the coated spherical graphite that is packed into the anodes of lithium-ion batteries.

According to USGS, the Middle Kingdom accounted for 82% of the world's mined graphite last year and produced nearly 100% of the battery-grade anode material.

With only limited supplies of graphite currently being mined in Canada and Mexico, and graphite anode material production at its earliest stages in the U.S., North American automakers are nearly 100% dependent on imports from China for this increasingly competitive product.

"North America produced only 1.2% of the world's graphite supply with production in Canada and Mexico," USGS inked in its 2022 minerals report. "Two companies were developing graphite mining projects in the United States—one in Alabama and one in Alaska."

Both these companies – Westwater Resources Inc. in Alabama and Graphite One Inc. in Alaska – have plans to develop both graphite mines and the processing facilities to produce the spherical graphite that serves as the anode material in most lithium-ion batteries.

Syrah Resources Ltd. is also scaling up the production of battery-grade anode materials at Vidalia, a facility in Louisiana that has attracted the attention of both Tesla Inc. and the U.S. Department of Energy.

Tesla entered into a deal to buy coated spherical graphite produced at Vidalia, and DOE has loaned Syrah $102.1 million to fund the expansion of this active anode material in Louisiana.

"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.

Ford Motor Company has also entered into a deal to off-take graphite from Syrah's Vidalia facility.

In Canada, Nouveau Monde Graphite Inc. is advancing a

GRAPHITE ONE INC.

Core from drilling a high-grade lens at Graphite Creek, a world-class deposit in Alaska that is the first link of Graphite One's proposed lithium-ion battery anode material supply chain.

complete supply chain to provide battery and EV manufacturers with zero-carbon graphite anode material from the hydro-powered mine and processing facilities it is developing in Quebec.

"We are making significant progress on our objectives at a time when the market is feeling the pressure of limited supply options, rising prices and complicated logistics," Nouveau Monde Graphite Chair Arne Frandsen said in March.

Alabama graphite

Alabama is rapidly emerging as a hub for the production of coated spherical graphite and the EVs that are driving enormous new demand for this anode material.

In April, Alabama Gov. Kay Ivey and Congressman Mike Rogers joined other state and local government policymakers and business leaders to break ground on a $202 million coated spherical graphite processing facility being developed by Westwater.

"Alabama, which is home to Mercedes-Benz, Honda, Hyundai, Toyota and Mazda, is among the top four states in the nation in automobile production," said Gov. Ivey. "This plant will make Alabama an even bigger player in the fast-growing electric vehicle sector."

The Mercedes EQS EV being produced in Alabama needs roughly 250 pounds of graphite for each 107.8 kilowatt-hour battery that provides this luxury sedan with an impressive 350 miles of range on a single charge.

While EV battery sizes vary by make and model, the Mercedes EQS represents a middle ground between more economical cars like the standard range Tesla Model 3, which needs about 120 lb of graphite for its battery, and full-size SUVs like the GMC Hummer, which requires roughly 500 lb of this anode ingredient.

With every major automaker on Earth electrifying their vehicles, there is massive new demand for the coated spherical graphite that will soon be produced at the Westwater facility in Alabama.

Alabama Graphite Products, a Westwater subsidiary, will use a proprietary process to purify raw graphite and refine it into battery-grade anode material.

Westwater says this process is safer and more environmentally friendly than the hydrofluoric acid-based process commonly used in China and elsewhere.

The initial phase of this processing plant, which is slated for completion by mid-2023, is designed to produce 7,500 metric tons of refined graphite.

"The construction of this plant is the result of a lot of work, cooperation, planning and vision by numerous people over a number of years," said Chad Potter, President and CEO of Westwater Resources and Alabama Graphite Products.

Last year, Gov. Ivey signed an incentive package that will provide Alabama Graphite Products with $29.9 million in jobs and tax credits over 15 years and $925,000 in job training and employee recruitment incentives for a facility.

"The cooperation and assistance we have received – from tax incentives to utilities to workforce development – has been incredible. We would not be here today without their support," Potter added.

In the beginning, the feedstock for the Alabama Graphite refinery will be imported, but Westwater intends to develop a mine at its Coosa project in the famed Alabama Graphite Belt by 2028.

According to a 2015 estimate, Coosa hosts 78.5 million metric tons of indicated resource averaging 2.39% (1.9 million metric tons) graphite.

Establishing a mine at Coosa would provide a much-needed local supply of graphite for the Alabama refinery and a new source of jobs for residents of Coosa County.

"As our investment of millions of dollars and our commitment to invest even more indicate, we are firmly committed to Alabama and this community, and we look forward to being here for many years to come," said Potter.

Alaska graphite

Much like Westwater, Graphite One Inc. is looking to establish a complete graphite anode material supply chain in the U.S., which would involve developing a mine at its enormous Graphite Creek deposit in Alaska that would provide the primary feed for a battery material processing and recycling facility in the state of Washington.

Located along Alaska's west coast about 50 miles north of the legendary gold mining town of Nome, Graphite Creek hosts 32.5 million metric tons of measured and indicated resources averaging 5.25% (1.7 million metric tons) graphite, plus 254.7 million metric

Right: Nouveau Monde's battery material plant in Becancour, Quebec, will upgrade graphite concentrates into battery-grade anode material and flake graphite for other industrial purposes.

NOUVEAU MONDE GRAPHITE INC.

tons of inferred resource averaging 5.11% (13 million metric tons) graphite.

A prefeasibility study finalized in August envisions a mine at Graphite Creek that would produce an average of 51,813 metric tons of graphite concentrate per year, which would be shipped to the company's planned facility in Washington where low-cost and low-carbon hydroelectricity will be used to upgrade the concentrates to spherical coated graphite and other products.

The capital cost to develop the mine and processing facility is estimated to be US$950 million, which includes a contingency of US$130 million.

With a post-tax internal rate of return (8% discount) of 22% and net present value of US$1.04 billion, the financially robust operations are expected to pay-back the capital in 5.1 years.

These figures do not take into account the tax credits offered to suppliers of EV battery materials under the Inflation Reductions Act.

Under this legislation, companies that produce lithium-ion battery materials in the U.S. qualify for a tax credit equal to 10% of the production costs. This credit begins fades by 25% per year starting in 2030.

The IRA also offers a second tax credit equal to 10% of the costs incurred in respect to the production of 99.9% graphite in the U.S. This credit does not have a sunset date.

The Graphite One projects detailed in the PFS are expected to qualify for both credits.

The company also plans to establish a lithium-ion battery recycling facility alongside its processing plant.

"With this new proposed recycling division joining our Graphite Creek mine and Advanced Graphite Materials Manufacturing Plant as the third link, Graphite One plans to bring the full circular economy to the U.S. graphite supply chain," said Graphite One President and CEO Anthony Huston.

Quebec graphite

Environmentally responsible production of EV anode material lies at the very foundation of Nouveau Monde's strategy to deliver carbon-neutral graphite from the supply chain it is developing in Quebec.

"Battery minerals cannot power a sustainable energy revolution unless their extraction and value-added transformation are done on a 'Zero-Harm' basis," said Nouveau Monde Graphite Chairman Arne Frandsen.

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.

This graphite concentrate will be trucked roughly 95 miles (150 kilometers) to the company's advanced material plant at Bécancour, where it will be upgraded to 42,616 metric tons of the coated spherical anode material for lithium batteries and 3,007 metric tons of large flake graphite for other industrial purposes.

"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.

As a forward-looking company that is supplying a vital ingredient to the lithium-ion batteries storing renewable energy and powering electric vehicles, Nouveau Monde is shrinking the carbon dioxide footprint of its Quebec operations.

To accomplish this, the company plans to have an all-electric fleet of mining equipment charged with Quebec's abundant hydroelectricity digging up and hauling the graphite at Matawinie.

This idea is so ahead of the curve that the electric mining equipment it plans to use has not been invented yet.

To overcome this hurdle, Nouveau Monde partnered with Caterpillar Inc. to develop, test, and produce a fleet of all-electric Cat mining equipment for its coming graphite mine in Quebec – a landmark collaboration for Nouveau Monde and the mining sector at large.

"We are proud to be a driving force for our peers as we strive to electrify our operations to meet our carbon neutrality commitments while maintaining the productivity and efficiency standards of our mining operations," said Desaulniers. "Even more gratifying and important to our corporate mission is that our project can serve as a springboard for the future of the mining industry by collaborating with Caterpillar on these cutting-edge technologies."

As an added bonus for Nouveau Monde, each of the battery-powered Cat mining machines will need about a ton of graphite.

Desaulniers told Data Mine North that battery manufacturers interested in securing Nouveau Monde graphite have expressed interest in supplying Caterpillar with the batteries to power its electric machinery at Matawinie and around the globe.

Nouveau Monde plans to begin delivering ESG-boosting graphite into EV supply chains in 2023.

"I am confident that the ESG-minded team at NMG can capitalize on our exclusive ecotechnologies and industry-leading practices to position the company as a Western World's trailblazer for competitive, sustainable, and local graphite advanced materials production," said Frandsen. DMN

Mercedes-Benz AG has also jumped onto the bandwagon for EV manufacturing, establishing a lithium-ion battery recycling factory in Kuppenheim, Germany.

MERCEDES BENZ

Urban mining to help fill critical deficit

Critical minerals and REEs can come from decades of e-waste

By A.J. ROAN

DATA MINE NORTH

THE NECESSITY OF RECLAIMING waste as a means to curb the seemingly impossible material requirements of a renewable future is fostering a different kind of industry – urban mining.

"When you're in the renewable energy space, you've got to think through the whole lifecycle – where will EV and lithium-ion batteries go when they are no longer useful? It can't be to a landfill. That's not responsible," said Graphite One President and CEO Anthony Huston during an announcement of its domestic advanced graphite material supply chain plan, which includes its own recycling facility. "Battery materials are simply too critical and too scarce to let them go to waste. That all points to recycling battery materials."

With technologies coming out of the woodworks to separate valuable critical minerals from expired batteries or broken electronics, to combat the fervent need for battery metals, many companies have begun developing methods to extract the wheat from the chaff, so to speak.

In this case, the wheat being the metals and minerals vital to making new batteries, and the chaff is everything else.

The challenges go beyond just separating these components. While methods to break down and then reuse materials have existed for hundreds of years, today's metal recycling companies are endeavoring to attain environmentally conscientious and sustainability standards that old technologies certainly did not take into consideration.

For if the reclamation of such necessary materials produces the very same pollutants it is striving to reduce, then the purpose is moot.

While mining companies are mobilizing the best they can within the constraints of regulations toward this paradigm shift of global energy, and refineries and facilities are sprouting up in economically viable and strategic locales, the fact of the matter is, it will not be enough.

And while recycling will eventually fill large portions of the world's EV and renewable energy mineral needs, it will require large-scale mining to feed EV markets with enough minerals and metals to prime a future circular economy.

Nevertheless, a handful of forward-thinking companies are preparing for that eventual outcome by developing technologies to

reprocess, repurpose, and recycle the minerals and metals essential to a green-driven world.

While a completed circle is many years away, there is no better time than now to prepare for when the life of today's EVs and renewable energy sources run their course, so future generations are not left with a bill they cannot pay.

LI-CYCLE HOLDINGS CORP.

Based on existing supply deals with industrial clients such as General Motors and LG, Li-Cycle estimates it could supply 15% of North America's battery manufacturing capacity by 2025.

RecycLiCo 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.

By dissolving cathode material from spent lithium-ion batteries or scrap from the manufacturing process, the company has shown that its approach can produce greater than 99.9% pure cathode material.

The company recently put its process through another round of rigorous scrutiny – conducting tests and audits to verify the capability and potency of its battery materials recycling and upgrade tech.

Initially, Kemetco Research Inc., a British Columbia-based analytics company that specializes in analytical chemistry and extractive metallurgy, carried out tests to determine the optimum processing capacity of a lithium-ion battery cathode scrap materials pilot plant.

The results were a C$2.7 million contract for Kemetco to develop a 500-kilogram-a-day demonstration recycling plant and the design of a five-metric-ton-per-day commercial recycling plant using the RecycLiCo process.

More recently, a complete "gate-to-gate" life cycle assessment was performed by Minviro Ltd., a UK-based and globally recognized sustainability and LCA consultancy, to quantify the environmental performance of producing nickel-manganese-cobalt cathode precursor and lithium hydroxide from recycled and upcycled battery waste.

"I am pleased to report that the LCA results confirm RecycLiCo's environmental impact to produce NMC precursor and lithium hydroxide, when compared to primary raw material extraction methods or competing hydrometallurgical recycling," said Larry Reaugh, president and CEO of RecycLiCo Battery Materials.

The report assessed RecycLiCo's process against competing hydrometallurgical recycling methods on the basis of producing one kilogram of nickel-manganese-cobalt precursor material. Such results included global warming potential, acidification potential, minerals and metals depletion, and fossil fuel depletion.

The RecycLiCo process was shown to produce only 7.1 kilograms of CO2-equivalent per kg of NMC precursor materials, 166% lower than the 18.8 kg for other hydrometallurgical methods.

Furthermore, according to RecycLiCo, this equates to 17,000 tons of CO2 per gigawatt-hour NMC battery material recycled, which is roughly equivalent to the average annual emissions of 3,700 internal combustion engine vehicles.

Minviro also found that RecycLiCo resulted in a 35% reduction in CO2-equivalent emissions for NMC precursor production and a 74% reduction for lithium hydroxide production compared to mining these materials.

"It was a pleasure working with Minviro over the past three months, and I'm extremely pleased with their detailed work in dissecting, evaluating, and quantifying the impact of every stream in our process," said Reaugh.

Li-Cycle spoke and hub

Known for its significant partnerships with General Motors, Glencore, and others, cooperation is the premise upon which Li-Cycle Holdings Corp. was founded as it endeavors to provide an end-of-life lithium-ion battery solution that creates a secondary supply of critical battery metals to meet increasing demand, while also ensuring a sustainable future for our planet.

Established in Ontario, Canada, Li-Cycle has developed its own method of safely and sustainably processing lithium-ion batteries by utilizing a unique and proprietary solvent extraction process via its "spoke and hub" model to recycle spent batteries.

With the spokes being a distribution network of how it will receive all types of lithium-ion batteries to transform them into an inert product to be shredded and separated, to utilizing the colloquially called "black mass" remnant – which is comprised of lithium, nickel, cobalt and graphite – at its hub location.

After its initial agreement with GM, Li-Cycle received a $200 million investment from Glencore plc, one of the world's largest global diversified natural resource companies and a major producer and marketer for more than 60 responsibly sourced commodities.

"We are excited to announce this new strategic partnership with Li-Cycle. We both believe that battery recycling will form a key part of the energy transition," said Kunal Sinha, head of recycling at Glencore and the agreed-upon nominee for Li-Cycle's board of directors. "Our bold aim is to help support the creation of a genuinely circular economy that supplies recycled materials and minerals back into the battery supply chain."

Furthermore, due to the company's potential, Li-Cycle was also recently selected as one of Canada's fastest-growing sustainable companies by Corporate Knights – a media, research and financial information products company based in Canada that has been producing global corporate and fund ranking for nearly 20 years.

Designed to highlight emerging Canadian

companies whose business activities align with the transition to a clean economy, the revenue, capital expenditure, acquisitions, research and development, and employment of more than 6,000 companies were taken into consideration before releasing its list of the final 50.

From Corporate Knights' calculations, Li-Cycle has had an 831% revenue growth in a single year, marking it as the third-highest fastest-growing company in Canada and establishing its place as a future sustainable powerhouse for western supply of recycled battery metals.

With the support of one of the world's largest automakers, another from one of the world's largest commodity drivers, and the endorsement of a prestigious ranking firm, Li-Cycle has cemented its position as a future circular economy gateway for North America.

Aqua Metals, Redwood Materials

As time goes by and the world moves full swing toward renewable energy, multitudes of startups, universities and research labs are catching on to the potential of urban mining, or recycling of the immense quantities of decades of electronic e-waste in landfills and dumpsites throughout the U.S.

Companies like Redwood Materials Inc. and Aqua Metals Inc.

Founded in 2017 by Tesla co-founder JB Straubel, Redwood Materials is a battery recycling company that has been quietly prepping for an energy transition before it became a well-circulated buzzword.

Like many other recycling companies, Redwood's goal is to recover materials from perhaps the largest lithium and cobalt deposits in the western hemisphere, the junk drawers of America.

Having insider information and experience from the company that kickstarted the global transition to full EV production, Straubel made the move to create a company designed to recycle and reuse the materials needed for what he helped build for nearly two decades.

The idea is to kickstart this endeavor by recycling the untold volume of consumer-level electronics over the last thirty years – phones, computers, televisions, indoor and outdoor appliances, video game electronics, toys, toiletries, the list could go on with microchips, batteries, transistors, and every other aspect that people have used to create electronic devices.

As it waits for early generations of EVs to reach their expiration date, Redwood is focused on a more grassroots and home-grown method of recycling, even going so far as to post on its website, "if you have old lithium-ion batteries or e-waste, we encourage you to send them for recycling! Redwood accepts phones, laptops, tablets, power tools, electric toothbrushes, wireless headphones, and any other rechargeable device with a lithium-ion battery."

Aqua Metals, however, has opted to take an industrial approach, utilizing its proprietary AquaRefining technology. As a water-based recycling technology that can recover metals at room temperature and is fundamentally non-polluting, the company utilizes an electroplating process that essentially builds metal one atom at a time to produce some of the purest recovered metals in the world, according to Aqua Metals.

Already proven with its Aqualyzer – which produces 99.996% lead, some of the purist on Earth, from recycled lead-acid batteries – it was a small mental leap to apply its expertise toward lithium-ion recycling, which the company believes has the lowest environmental footprint of any technology under development.

In addition to lead and lithium batteries, Aqua Metals has also produced high-purity lithium hydroxide – used to make soaps for thickeners in lubricating greases – as well as copper, a metal critical to wiring the renewable energy future.

With these two companies, and countless others not mentioned, it is evident that there will be no small amount of competition when it comes full circle and the batteries and electronics of today reach the end of their life spans and can be repurposed into a new product once more.

March of the giants

The true movers and shakers of the renewable energy transition are the vehicle manufacturers.

With GM going so far as to completely rebrand, going all-in for its line of Ultium EVs, and Volkswagen having long prepared to recycle EV lithium-ion batteries before even having a complete fleet – if there is one thing these companies want, it's to sell cars.

However, none of them can do so without the necessary materials. Foreseeing the demand for lithium-ion batteries outweighing the supply of the raw materials needed to make them, many automakers have begun to establish in-house or partnerships with companies that can recycle those spent EV batteries.

Perhaps, GM global chief marketing officer Deborah Wahl said it best regarding today's green transition.

"There are moments in history when everything changes. Inflection points. We believe such a point is upon us for the mass adoption of electric vehicles."

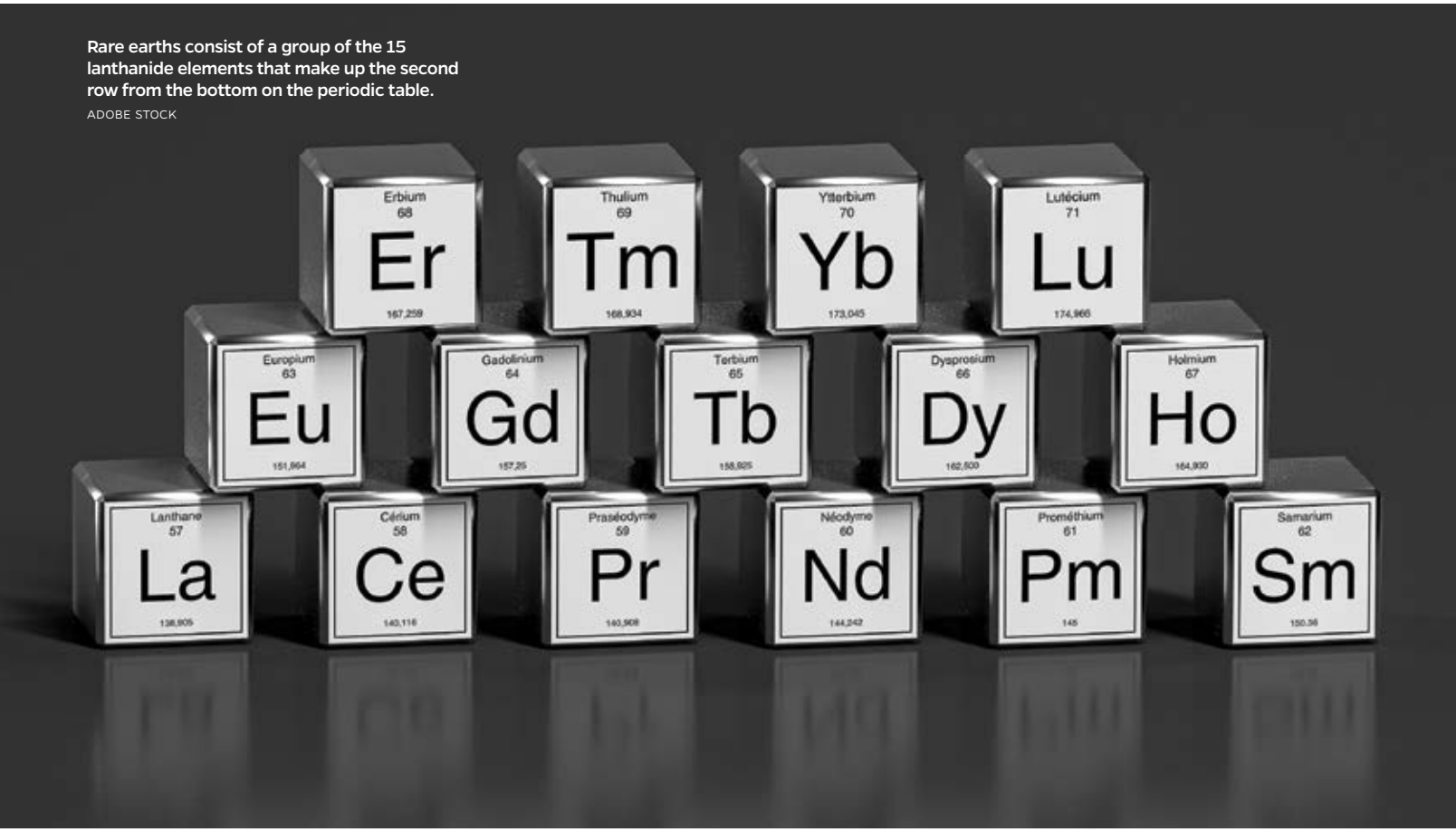
How right she was.

BMW, Ford, Honda, Mercedes-Benz, Nissan, Tesla, Toyota, Volvo, the list could go on, as multitudes of partnerships, strategic alliances, and investments are being made in a mad dash to solidify its position in a future green world.

Tens of billions of dollars thrown into these operations suggest that they mean business, and the wiser companies have begun partnering with battery manufacturers, who themselves have partnered with battery recyclers or who themselves recycle batteries.

While most do not expect any appreciable quantities of spent batteries for at least another decade, it is clear that a growing list of innovative companies have seen the bigger picture and are looking beyond the present supply chain concerns.

While the going continues to be rough to meet the demand projected by industry analysts, once the cycle is completely underway, these companies will be well established when the need to recycle battery materials back into the circular economy fully emerges. DMN



Rare earths consist of a group of the 15 lanthanide elements that make up the second row from the bottom on the periodic table.
ADOBE STOCK

Rare earths 101 – a crisis of identity

Getting to know each element key to understanding REE markets

By SHANE LASLEY
DATA MINE NORTH

RARE EARTH ELEMENTS SUFFER from a crisis of identity. Often referred to and treated as one commodity, REEs are actually a group of 15 elements – each with its own individual and seemingly magical qualities.

"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.

The seemingly magical properties of rare earths make the modern high-tech world possible.

"Because of their unusual physical and chemical properties, the REEs have diverse defense, energy, industrial, and military technology applications," the U.S. Geological Survey wrote in a 2018 report on minerals and metals critical to America's economic and national security.

Some of the seemingly magical elements are responsible for the brilliant colors on televisions, computer monitors, and smartphone screens; others go into the powerful magnets that allow high-fidelity speakers that are small enough to fit into your ear, electric cars that travel further on a charge, and efficient wind turbines; a few are used to boost fiber optic signals that make the internet faster; one rare earth is responsible for the world's most accurate atomic clock; a couple more are used for portable X-ray machines that do not need electricity; others are used in a device that turns any flat surface into a speaker; and this growing list goes on.

It is not rare earths in general, however, that make these modern wonders possible. Instead, each individual element – except for promethium, which is extremely rare in nature – lends its own special qualities to marvels of our modern world.

Rare earth elements could be thought of as a spice rack for modern high-tech, green energy, and military technologies. Instead

■ *For a complete list of the 15 rare earths and a brief description of their individual applications can be found at* ***Rare earth elements and how they are used*** *on page 50.*

of 11 secret herbs and spices for finger-licking good chicken, this rack has 15 elements that have helped to upgrade the black and white TV sets of the 1960s to ultra-high-definition flat screens capable of streaming Netflix in more than 1 billion colors.

And just like spices, each individual rare earth brings its own zest to modern devices. While a pinch of dysprosium ensures powerful permanent magnets stay magnetized in high-heat situations, for example, it is a poor substitute for making the terbium green, which is one-third of the trichromatic lighting tech trifecta.

So, while rare earths are the spice rack of modern technologies, understanding the flavor of each rare earth will help demystify this group and allow each element to exercise its individuality – an understanding that is becoming increasingly important as the green energy transition spices up magnets used in EVs and wind turbines with rare earths, while leaving the rest of this group of elements on the rack to collect dust.

Dysprosium and terbium oxides produced from MP Materials Mountain Pass Mine in California.

MP MATERIALS CORP.

"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," the International Renewable Energy Agency inked in a 2022 report on rare earths.

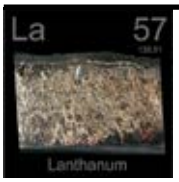
"It is critical to understand individual REE, instead of dealing with them as a group," IRENA added.

Always found together

To be fair, there are good reasons that rare earths lack individuality – these lanthanide elements are so chemically similar that they are grouped together and given their own individual line near the bottom of the periodic table; they hang out together in nature – where you find an economic deposit of one, the 13 other stable

Continued on page 52

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.

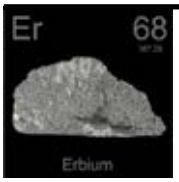
Europium L P – This element is widely used to create blue and red phosphors for televisions and computer monitors, as well as producing a more natural white light for fluorescent bulbs. Coincidentally, europium's distinct red glow under UV light is leveraged for anti-forgery marks on Euro banknotes. 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.

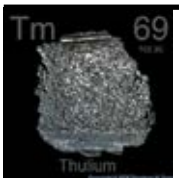
Terbium M P – High-temperature magnets made with terbium are used in EVs and wind turbines. A terbium alloy that expands or contracts in the presence of a magnetic field is used to make a SoundBug, which creates a vibration that turns any flat surface it is placed on into a speaker. Terbium is also used 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.

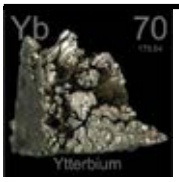
Holmium M La – With the highest magnetic strength of any element on the periodic table, holmium is used to create the strongest artificial magnetic fields. This property is used primarily in magnetic flux concentrators, which can intensify and direct a magnetic field. Holmium-doped garnets are used in lasers for eye surgery and can destroy cancerous tumors with minimal damage to the surrounding tissue.



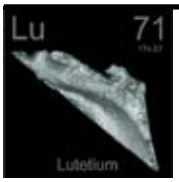
Erbium La G – Amplifying the signal of fiber optic cables carrying data over long distances is a major use for erbium. This element, along with vanadium, is used in alloys to increase the pliability of metals. Garnets in lasers used for tattoo removal and other skin resurfacing, a pink colorant for sunglasses and imitation gems, and infrared absorbing safety glasses for welders are other uses for this rare earth.



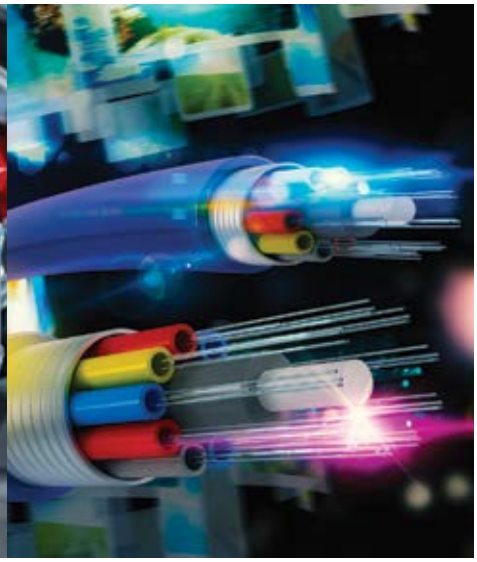
Thulium La – Like many of the other rare earths, thulium is used in precision lasers for surgical applications. When bombarded by neutrons, thulium becomes radioactive thulium-170 (128.6-day half-life), which ejects soft gamma radiation that can be used for portable X-ray devices. Euro banknotes also 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.



REETEC

Above: Rare earths can be thought of like spices, with each individual element adding its own zest to a wide array of household, high-tech, and green energy goods. **Right:** Electric vehicles and wind turbines are creating enormous new demand for magnet rare earth elements such as dysprosium, praseodymium and neodymium.

PIXABAY

rare earths are always present in some quantity; and they were given such hard-to-pronounce names that it is just easier to call them by their family title.

Adding to their individuality crises, an en vogue media trend to refer to any of the less abundant critical minerals and metals as "rare earths" adds an extra layer of befuddlement that is akin to calling dairy products spices – they do add flavor to recipes (especially butter), but they do not belong on the spice rack.

But I digress.

The primary reason rare earths are considered a group instead of individuals is their geological affinity, and when you mine one, you mine them all. There are no lanthanum, praseodymium, or ytterbium mines – just rare earth mines.

Each deposit has its own unique ratio of each of the 14 stable rare earths, but any given REE orebody has at least some of all of them. Considering that each individual rare earth has its own price driven by supply and demand – for example, at mid-year lanthanum oxide was selling for about US$1.45 per kilogram while terbium oxide was fetching a whopping US$3,500/kg – the value of an REE deposit is determined by how much of each element is present.

And the flavors of the day are the rare earths used in the magnets going into EVs, wind turbines, and high-tech devices – praseodymium, neodymium, samarium, gadolinium, terbium, dysprosium, and holmium. So, a mine that produces high quantities of these elements is much more valuable than one that is more enriched with cerium, lanthanum, and thulium.

A mine more enriched in the more sought-after magnet rare earths is also putting smaller quantities of the lesser-used REEs on the rack to collect dust.

In reality, the less popular REEs often do not even make it to the spice rack. Instead, mining and separation projects often toss the less sought-after rare earths in a bargain bin of mixed REEs after the more cherished elements are pulled out.

Tight bonds

Adding further to rare earths' lack of individuality is their affinity for one another, which makes them notoriously difficult to separate.

Much like fraternal twins, the 14 stable rare earths may look and act differently but have some undeniable similarities. A key likeness is the outermost electron shell of all the REEs are identical; this is why they are always found together geologically and difficult to separate into individual elements once mined.

To separate the tightly bonded rare earths into the individual elements that spice up technologies, an arduous process called solvent extraction was invented.

The basic idea behind solvent extraction, which has served as the standard for separating REEs for the past 60 years, is a mixed rare earth product is bathed in vats of various solvents that progressively separate the notoriously interlocked rare earths into individual elements – a long process that requires dozens of steps and a relatively large environmental footprint.

The real trick to ensuring there are plenty of rare earths to meet global demand is not in finding REE deposits; they really are not as rare as their name suggests, but in developing environmentally sound processes to separate the group into the individual elements that spice up modern technologies.

From the millions of dollars being invested by the U.S. government to more modest investments by small-cap mining companies seeking the most value from their REE deposits, the quest for a superior rare earth separation tech has drawn a lot of attention. DMN

*Find out more about the U.S. government's nearly $300 million investment in domestic rare earth processing facilities and the companies building REE separation capacity in North America at **Making rare earths separation less rare** on page 54.*

METAL TECH NEWS

Discover more at www.metaltechnews.com

The Round Top deposit rising out of the West Texas desert could provide a domestic source of rare earths, lithium, and other minerals critical to the U.S. for nearly a century.

TEXAS MINERAL RESOURCES CORP.

Making rare earths separation less rare

US invests heavily into developing REE processing facilities

By SHANE LASLEY

DATA MINE NORTH

DESPITE WHAT THEIR NAME suggests, rare earths are not all that scarce. An efficient and environmentally sound technology capable of separating this tightly bonded group into the 15 individual elements of innovation, however, is truly unique and the key to establishing a rare earths supply chain in North America.

There are currently no commercial-scale rare earths separation facilities in North America and only two such facilities outside of China – one in Malaysia and the other in Estonia – though other such plants outside of Asia are under development.

In North America, the need to establish this fundamental link between rare earths enriched deposits and the downstream electric vehicle, renewable energy, high-tech, and other sectors demanding ever-increasing quantities of these critical elements is not lost on governments or industry.

The United States government alone is investing hundreds of millions of dollars into establishing this vital middle link of the rare earths supply chain.

At the same time, global automakers, mining companies, recycling firms, and others in the private sector are racing to develop enough rare earths separation and processing capacity to meet the enormous demand for this group of elements, especially the magnet rare earths needed for EV motors, wind turbine generators, computer hard drives, hi-fidelity speakers, and a wide array of other products.

This effort to decentralize the REE supply chain away from China, however, has gained the attention of a cybernetwork that pushes online narratives in support of the People's Republic of China's political interests.

Known as Dragonbridge, this group has launched a campaign

targeting companies advancing rare earths mining and processing projects in the United States and Canada.

"Dragonbridge's targeting of the rare earths industry … demonstrates an interest in industries of strategic importance to the PRC that we had not previously observed from the campaign," Mandiant, a cybersecurity firm that has been tracking Dragonbridge's pro PRC campaigns for three years, inked in a June blog.

Innovation Metals technicians testing Ucore Rare Metals' RapidSX rare earth separation technology.

UCORE RARE METALS INC.

Pentagon funds Texas REE plant

The primary target of the Dragonbridge rare earths campaign was Lynas Rare Earths Ltd., which secured $150 million in Pentagon funding to establish a rare earths processing facility in Texas that will ensure the military and industrial sectors in the U.S. have a secure supply of rare earths.

In June, the U.S. Department of Defense agreed to invest $120 million to fund a heavy rare earths separation facility to be owned and operated by Lynas USA LLC, a subsidiary of Australia-based Lynas. This facility is to be built alongside a $60 million light rare earths separation facility that is being co-funded by the Pentagon and Lynas.

"The U.S. Government's selection of Lynas for this strategic contract reflects our proven track record in rare earths production," said Lynas Rare Earths CEO and Managing Director Amanda Lacaze.

Owner of the Mt. Weld rare earths mine in Western Australia and an REE separation facility in Malaysia, Lynas was the first company in decades to commercially mine and process rare earths outside of China.

The two contracts with the Pentagon provide the company with US$150 million to fund a facility in the U.S. with the capacity to produce the entire suite of rare earths.

The distinction between light and heavy rare earths is primarily a function of the atomic weight of each element.

Most rare earth deposits contain some mixture of the 15 lanthanides, a group of elements in their own row near the bottom of the periodic table, plus yttrium and scandium, which are also often considered REEs.

Light rare earths make up the first eight elements of the lanthanide series. This subset includes lanthanum, for which the series gets its name; cerium, used for polishing high-quality optical surfaces; praseodymium, valued for its magnetic and optical properties; and neodymium, the main rare earth used in the neodymium-iron-boron magnets used in EV motors and wind turbine generators.

The remaining seven lanthanides are considered heavy rare earths, which are less abundant in most deposits and tend to be more valuable. This subgroup includes europium, used primarily in red and blue phosphors in televisions and computer monitors; terbium, used in high-temperature magnets and to create a green phosphor; and dysprosium, which improves the durability of magnets in EV motors and wind turbine generators.

China's dominance in mining and especially the separation of rare earths is the reason former President Donald Trump and current President Joe Biden authorized the Pentagon to use Defense Production Act Title III funding to support the development of a domestic supply chain of these suite elements critical to national defense and homeland security.

In 2021, DoD agreed to invest up to US$30 million of DPA Title III funding to help build a light rare earths separation facility to be developed and equally co-funded by Lynas.

Under the latest DPA Title III contract with Lynas, DoD will fully fund a heavy rare earths separation capacity to be developed alongside the light REE facility.

"The DoD's decision to fully fund the construction of the heavy rare earths facility demonstrates the priority that the U.S. government is placing on ensuring that supply chains for these critical materials are resilient and environmentally responsible, and as importantly, their confidence in Lynas' ability to execute, including access to quality feedstock and processing expertise," said Lacaze.

It also put Lynas and DOD in the crosshairs of Dragonbridge.

With thousands of fake Twitter and Facebook accounts, Dragonbridge operatives posed as concerned Texas residents protesting the construction of Lynas' proposed rare earths processing plant and criticizing the Biden administration's decision to support the facility.

The Pentagon launched an investigation into Dragonbridge disinformation campaign and said it "remains committed to working with industry, the interagency, and partner nations to promote resilient, environmentally sustainable, and transpar-

ent supply chains for critical minerals and materials, both domestically and around the globe."

This includes continued support of Lynas' plans to develop a rare earths separation plant within an existing industrial area on the Texas Gulf Coast.

Feedstock for this facility is expected to initially be mixed rare earths carbonate produced from material mined from Mt. Weld.

Lynas anticipates the Pentagon-funded heavy rare earths facility in Texas will be operational by mid-2025.

DoD funding for MP separation

Not putting its eggs all in one basket, the Pentagon also awarded MP Materials Corp. a $45 million contract to commercially separate rare earth elements at its Mountain Pass Mine in California's Mojave Desert.

Mountain Pass is currently the only mine in the United States that produces rare earths. Due to the lack of separation capacity elsewhere, MP ships mixed rare earth concentrates produced at the California mine to China to be separated into their individual elements.

Similar to its deal with Lynas, Department of Defense first committed $9.6 million to restore Mountain Pass' ability to separate and purify light rare earths and then awarded a $35 million contract to commercially separate and refine heavy REEs.

"The ability to mine, process, and refine rare earths at Mountain Pass is foundational to a national effort to secure the U.S. rare earth supply chain," said MP Materials Chairman and CEO James Litinsky. "We thank the Department of Defense for its confidence and support."

This ability to mine and refine the entire suite of rare earths comes at a time when the rapid rise of EV manufacturing is creating massive new demand for powerful REE magnets.

To ensure that it has a reliable supply of the materials needed to build the electric mobility it envisions, General Motors recently cut a deal to buy REE materials and magnets to be produced at a new facility that MP Materials is building in Fort Worth, Texas.

DOE puts up $140 million

As the Pentagon backs Lynas' Texas REE separation plant, the U.S. Department of Energy is investing nearly as heavily into the development of a facility capable of extracting rare earths and other critical minerals from unconventional sources such as coal ash and acid mine drainage, and then refining them into the individual metals.

Above: The United States is investing heavily into facilities to separate rare earths into the individual elements needed for high-tech applications. Clockwise from top center: praseodymium, cerium, lanthanum, neodymium, samarium, and gadolinium.

"Applying next-generation technology to convert legacy fossil fuel waste into a domestic source of critical minerals needed to strengthen our supply chains is a win-win – delivering a healthier environment and driving us forward to our clean energy goals," said U.S. Secretary of Energy Jennifer Granholm.

The $1 trillion Bipartisan Infrastructure Law included $140 million to support this altruistic objective.

"With the Bipartisan Infrastructure Law's investment in the build out of this first-of-its-kind critical minerals refinery, we are moving ideas from the lab to the commercial stage and demonstrating how America can compete for the global supply chain to meet the growing demand for clean energy technology," the energy secretary added.

To put the best ideas and technologies into this critical demonstration refinery, DOE has gathered input from industry, investors, developers, academia, research laboratories, government agencies, non-governmental organizations, and communities that potentially could be affected by the development of the critical minerals plant.

While DOE encourages outside-of-the-box thinking when it comes to unconventional sources of critical minerals, it does not want to stray too far from convention when it comes to the technologies that will be used to extract and refine these technology metals.

The energy department envisions that this first-generation separation facility will use proven methods such as hydrometallurgy and solvent extraction for the separation of individual rare earth and critical mineral oxides, as well as the subsequent refining and alloying of metals.

Rare earths separation upgrade

RapidSX, a technology developed by Ucore Rare Metals Inc.'s subsidiary Innovation Metals Corp., seems to meet the energy department's criteria.

Fundamentally, RapidSX is a 21st-century upgrade to the conventional solvent extraction technology that has been the standard for separating rare earths in China for more than 40 years.

Traditional solvent extraction involves running a mixed rare earths product through vats of various solvents that progressively separate the notoriously

PEGGY GREB, U.S. DEPARTMENT OF AGRICULTURE

interlocked rare earths into individual elements – a long process that requires dozens of steps and a relatively large environmental footprint.

Utilizing an innovative column-based platform developed by IMC, RapidSX is much faster and more environmentally sound than the mixer-settler units used for traditional SX separation.

Ucore intends to install this technology at its Alaska Strategic Metals Complex, a processing plant it plans in Ketchikan, a port town in Southeast Alaska. This facility, slated for completion in 2024, would provide a domestic supply of rare earths.

AG Hydrometallurgy Services Inc., which was hired by the Alaska Industrial Development and Export Authority to carry out an independent technical review of commercializing RapidSX, found this tech has the ability to separate the entire suite of rare earths around three times more efficiently than traditional solvent extraction.

"After completing our extensive technical review of the RapidSX technology, its commercialization development process and its planned installation in the Alaska SMC, it is my opinion that Ucore can credibly and effectively execute its unique business strategy," said AG Hydrometallurgy Services President and CEO Ahmad Ghahreman, a hydrometallurgical expert that has advised the Canadian government on rare earths mining and separation.

■ *Further details on rare earth magnets, including General Motors' agreement with MP Materials to build an REE magnet plant in Texas,, can be read at* ***7 world transforming rare earths*** *on page 58.*

Compared to conventional solvent extraction with the same capacity, a RapidSX separation facility would cost around half to build and approximately 20% less to operate.

Ucore has already lined up supplies of mixed rare earths in need of being separated into individual elements of innovation.

This includes an agreement to process mixed rare earth carbonates derived from Vital Metals Ltd.'s Nechalacho Mine in Northwest Territories, the only REE operation in Canada.

High-grade ore mined at Nechalacho is upgraded to a concentrate with x-ray transmission (XRT) sorting technology and then shipped to Saskatchewan, where it is being refined into a mixed rare earths carbonate.

A portion of this mixed REE product is tentatively slated for future shipments to the Alaska SMC.

"This agreement is an important and exciting entrance into the North American downstream rare earth supply chain," said Vital Metals Managing Director Geoff Atkins. "We are particularly excited that … Ucore represents the most advanced new rare earth separation company entering into the North American market."

Rare Earth USA supply chain

USA Rare Earth LLC, which is developing a domestic mine-to-magnets rare earths supply chain, was another target of Dragonbridge's rare earths disinformation campaign on social media.

The first link of the USA Rare Earth supply chain is the Round Top critical minerals mine project in Texas.

Being advanced toward production under a joint venture between USA Rare Earth (80%) and Texas Mineral Resources Corp. (20%), the Round Top project southeast of El Paso hosts an enormous deposit of rare earths, lithium, and six other minerals critical to the economic wellbeing and security of the U.S.

"USA Rare Earth is developing a fully domestic mine-to-magnet supply chain, while the lithium at Round Top will also support the manufacture of battery electric vehicles," said USA Rare Earth President Thayer Smith. "Our project is a geologically unique and diverse deposit that will help bolster U.S. critical minerals production."

A 2019 economic and engineering study for Round Top outlines plans for a mine that would produce 2,212 metric tons of rare earths per year, including healthy supplies of the six rare earth elements used in permanent magnets.

At the rate of mining considered in this economic assessment, Round Top hosts enough rare earth and critical mineral resources to operate for more than a century.

The Texas mine site will also host a facility that employs continuous ion exchange technology to separate the tightly interlocked rare earths into individual elements.

The final link of the USA Rare Earth supply chain will be a facility in Oklahoma that will produce rare earth magnets.

In June, the company announced that it purchased a 309,0000-square-foot building in Stillwater, an Oklahoma city that boasts a growing high-tech economy, to house its rare earth elements processing and magnets plant.

Having already purchased neodymium-iron-boron permanent magnet manufacturing equipment that Hitachi Metals America briefly used at a facility in North Carolina about a decade ago, USA Rare Earth already has all the major pieces needed to begin producing rare earth magnets in Oklahoma.

Advancing projects that could help break China's decades-long monopoly of rare earths mining, separation, and magnet making drew the attention of Dragonbridge, which launched a social media disinformation campaign against the Oklahoma facility.

Mandiant says the attack on USA Rare Earth, Lynas, and others advancing REE projects in North America underscores Dragonbridge's "ability to monitor developments and respond accordingly, as well as its investment in attempting to ensure the PRC's market dominance in the industry."

Pini Althaus, founder and advisor at USA Rare Earth, says he is not surprised by a China-sponsored campaign to sabotage and spy upon companies at the forefront of developing the burgeoning rare earths supply chain in North America.

"Sadly, it is a given," he posted on LinkedIn. DMN

Drilling at Ucore Rare Metals' Bokan Mountain project in Southeast Alaska has outlined a rare earth elements deposit at Dotson Ridge enriched with the critical metals niobium, zirconium, beryllium, hafnium, titanium, and vanadium.

UCORE RARE METALS INC.

7 world transforming rare earths

Magnet REEs turn motion to energy; energy to motion and music

By SHANE LASLEY

DATA MINE NORTH

WHILE ALL 15 OF THE RARE EARTHS have special properties that have been called magical, alchemistical, and futuristic, seven of these elements are imbued with a powerful magnetism that is hard to resist when it comes to creating a high-tech future powered by clean energy.

The magnetic qualities of these rare earths – praseodymium, neodymium, samarium, gadolinium, terbium, dysprosium, and holmium – are used to transform a summer breeze into low-carbon electricity via wind turbines, convert that energy back into whisper-quiet acceleration in electric vehicles, create the good vibrations in high-fidelity speakers small enough to fit into your ear, provide the powerful magnetic fields that allow MRI machines to create detailed images of organs and tissues, and a plethora of other modern wonders.

"Rare earth magnets are essential for U.S. economic and national security, and it is vital to our national interest that we manufacture these components at scale here at home," said Congresswoman Beth Van Duyne, R-Texas.

Roughly one-third of all the permanent rare earth magnets produced in 2020 went into wind turbines and EVs, according to a report published earlier this year by the International Renewable Energy Agency. With the number of wind turbines installed expected to double and EVs traveling global highways expected to grow by orders of magnitude by the end of the decade, low-carbon energy and transportation are expected to power massive new demand for rare earth magnets in the coming years.

"Although there are sufficient known rare earth resources to supply all the needs of the energy transition, the main challenge is to expand mining and processing activities across the entire value chain in line with demand growth," IRENA penned in its report, "Critical Materials for the Energy Transition: Rare Earth Elements."

EVs drive REE magnet demand

Due to the sheer magnitude of the automotive sector and the speed of the planned transition from fossil fuel-burning engines to electric drives, EVs will be the primary driver of rare earth magnet demand over the coming decades.

From the speakers and microphones connected to the infotainment system to the tiny motors swishing windshield wipers and locking doors, rare earths are found throughout EVs – or any modern vehicle for that matter. The motors that power EVs from 0-60 miles per hour in under three seconds, however, typically require more than 10 times the REEs than the rest of the vehicle combined.

It is estimated that the average hybrid or plug-in EV requires between 2.5 and 11 pounds of rare earth magnets. Though this is not a lot per vehicle, it is adding up fast as global automakers phase out internal combustion engine models in exchange for more electrifying cars, trucks, and SUVs over the coming two decades.

It is estimated that roughly 30 million EVs will be sold each year by 2030, which is ten times the 3 million sold in 2020, and this number is expected to continue to climb to 82 million per year by 2040. This ramping up of electric mobility is driving enormous new demand for rare earths, especially in the neodymium-iron-boron magnets that allow traction motors to more efficiently transform electricity into acceleration.

While neodymium gets top billing, NdFeB magnets typically have at least two magnet rare earths in them.

More often than not, the neodymium in these magnets is actually a neodymium-praseodymium alloy. Found side-by-side on the periodic table, these two rare earth elements have very similar properties, are always found together in nature, and are very difficult separate. So, it is usually easier and more economical to let them stay together when making magnets.

The magnets going into EVs and wind turbines typically also have significant amounts of dysprosium or terbium added to improve performance at high temperatures. Both elements fall into the category of heavy rare earths, which are much less abundant than the light REEs such as neodymium and praseodymium.

Dysprosium, which also offers thermal stability to magnets, is the preferred heavy REE additive to EV and wind turbine magnets. However, in terms of relative abundance in the Earth's crust, dysprosium is less than 1% of all REEs.

"The world's dysprosium supply is even more constrained than the neodymium supply, and this may pose a problem for the energy transition," IRENA penned in its rare earths report.

GENERAL MOTORS

General Motors is building a secure, scalable, and sustainable supply chain for rare earths and other materials needed for its growing lineup of electric vehicles, such as the GMC Hummer EV pictured above.

MP MATERIALS CORP.

MP Materials CEO James Litinsky (below) addresses the audience at an event commemorating the ground-breaking of a new facility in Texas that will offer a reliable and environmentally sound source of rare earth magnets for General Motors and others.

The dysprosium problem

The EV revolution that is demanding unprecedented quantities of the powerful neodymium-praseodymium magnets made more durable with dysprosium or terbium is driving a potential rare earths supply problem.

Global strategic minerals and metals analyst Adamas Intelligence expects EVs alone to account for around 25% of global NdFeB magnet consumption by 2030, a market share that will continue to grow as more drivers trade in ICE vehicles in favor of EVs.

This has automakers scrambling to either find adequate sources of rare earths for the magnets needed for the growing lineup of electrified models or looking into motor alternatives that lessen or eliminate the need for REEs altogether.

Falling into the former camp, General Motors cut a deal to buy rare earth materials and magnets from MP Materials Corp, which owns the Mountain Pass Mine in California's Mojave Desert and is building a 200,000-square-foot REE processing and magnet facility in Texas. Upon completion, this will establish a complete rare earths mine-to-magnets supply chain in the U.S., an area that is currently dominated by China.

"The United States needs to do everything we can to end our dangerous dependence on China for rare earth elements and critical minerals across the entire supply chain," said Sen. Ted Cruz, R-Texas. "It is both significant and important that MP Materials is going beyond mining and into alloying and manufacturing, and I'm deeply proud of the role Texas is playing in these projects."

The Lone Star State manufacturing plant, which is expected to begin ramping up production in 2023, will initially have the capacity to produce roughly 1,000 metric tons of finished neodymium-iron-boron magnets per year, enough for approximately 500,000 EV motors.

"We are building a resilient and sustainable EV manufacturing value chain in North America, from raw materials to cell manufacturing to electric drive motors and beyond, further accelerating

MP MATERIALS CORP.

GM's vision to support a mass market for EVs," said Shilpan Amin, vice president of global purchasing and supply chain at GM. "Our work with MP Materials is another bold step forward that will help ensure that we meet our goal to lead the EV industry in North America in more than just sales."

The Texas facility will also serve as the business and engineering headquarters for MP Magnetics, the company's growing magnetic division.

"MP Materials has built an exceptional magnetics team and important commercial relationships that will accelerate our mission to restore the full rare earth supply chain to the United States," said MP Materials Chairman and CEO James Litinsky.

Toward an overall strategy to ensure that it does not need to rely on China for the rare earth magnets it needs to fulfill its mission to get "everybody in" an EV, GM has also entered into a deal with Germany-based Vacuumschmelze, or VAC, to set up another U.S. factory to supply the Detroit automaker with rare earth materials and magnets.

"VAC's deep magnetic materials knowledge and extensive e-mobility technology expertise, in partnership with GM, will enable a cleaner global future for our communities," said VAC CEO Erik Eschen.

As GM focuses its efforts on securing plentiful supplies of magnet rare earths, BMW, Tesla, Toyota, Volkswagen, and other automakers are looking into lowering or even eliminating the need for these metals in their EV drive motors.

By creating magnetism with an electric current, EV drive motors can be made without rare earths. These wound rotor and induction motors, however, draw much more power from the battery pack, which means larger batteries and less range.

"Currently, NdFeB magnets are essential for optimising the power-to-weight ratio in motors and generators," according to IRENA.

A heavy REE alternative

It is not so much the potential shortages of neodymium that have automakers and wind turbine manufacturers worried. Instead, it is not having enough of the dysprosium that allows motors and generators to continue to operate efficiently at high temperatures that has engineers working overtime to come up with alternatives.

"Although heavy REEs are scarce and sourced from limited areas, production of neodymium is expected to keep pace with growing demand, even under ambitious scenarios for growth in electric machines using permanent magnets," IRENA wrote. "Where technological advances will be essential, however, is in finding substitutes for dysprosium, which is used to improve the upper-limit temperature performance of generators and traction motors using permanent magnets."

Developing REE deposits more richly endowed with the scarcer and more valuable heavy rare earths such as dysprosium is another alternative.

Round Top, an enormous rare earths deposit in Texas that is also enriched in lithium and other minerals considered critical to the U.S., happens to have a particularly enticing dysprosium-to-other rare earths ratio.

A preliminary economic assessment outlines plans for a mine at Round Top that would produce 2,212 metric tons of rare earths per year, including healthy supplies of all six permanent magnet rare earth oxides – 200 metric tons of dysprosium, 180 metric tons of neodymium, 67 metric tons of praseodymium, 65 metric tons of gadolinium, 65 metric tons of samarium, and 23 metric tons of terbium – once the mine reaches full production.

In addition, the mine summarized in the PEA would produce about 10,000 metric tons of lithium per year, which would help fill the expanding electric vehicle battery market.

Based on the current resource, the Round Top deposit is large enough to supply the REEs, lithium, and other critical minerals at this rate for more than a century.

USA Rare Earth LLC, which owns an 80% interest in Round Top, is advancing a complete rare earth mine-to-magnets supply chain that includes a mine and separation facility in Texas and a magnets plant to be developed in a 309,0000-square-foot building it recently acquired in Oklahoma.

"Currently, the United States, European Union, Japan, and much of the developed world is largely reliant on China for critical rare earth element production," said USA Rare Earth President Thayer Smith. "Our goal with this project is to advance U.S. manufacturing capacity by establishing the first vertically integrated domestic supply chain for rare earth elements, and we are excited to be working in Oklahoma."

In 2020, USA Rare Earth purchased nearly new neodymium-iron-boron permanent magnet manufacturing equipment that Hitachi Metals America briefly used at a facility in North Carolina about a decade ago. This is currently the only such sintered rare earths magnets manufacturing equipment in the western hemisphere, and it is to be installed at the company's newly purchased building.

>> *"Currently, the United States, European Union, Japan, and much of the developed world is largely reliant on China for critical rare earth element production."*

–USA Rare Earth President Thayer Smith

This provides Oklahoma a firm foothold in the renewable energy and high-tech economy.

"Oklahoma has long been on the cutting edge of energy innovation, and this project embodies the energetic, forward-thinking mentality of our state," said Oklahoma Governor Kevin Stitt. "The USA Rare Earth project will help our state remain a leader in domestic energy production, further diversifying our economy while reducing U.S. dependence on foreign imports."

USA Rare Earths anticipates that both its Round Top critical minerals mine in Texas and Stillwater rare earths metal and magnet manufacturing plant in Oklahoma to be operational in 2023.

Heavy REEs in Alaska

The Dotson Ridge deposit at Ucore Rare Metals Inc.'s Bokan Mountain project in Alaska is also weighted with heavy rare earths and critical minerals.

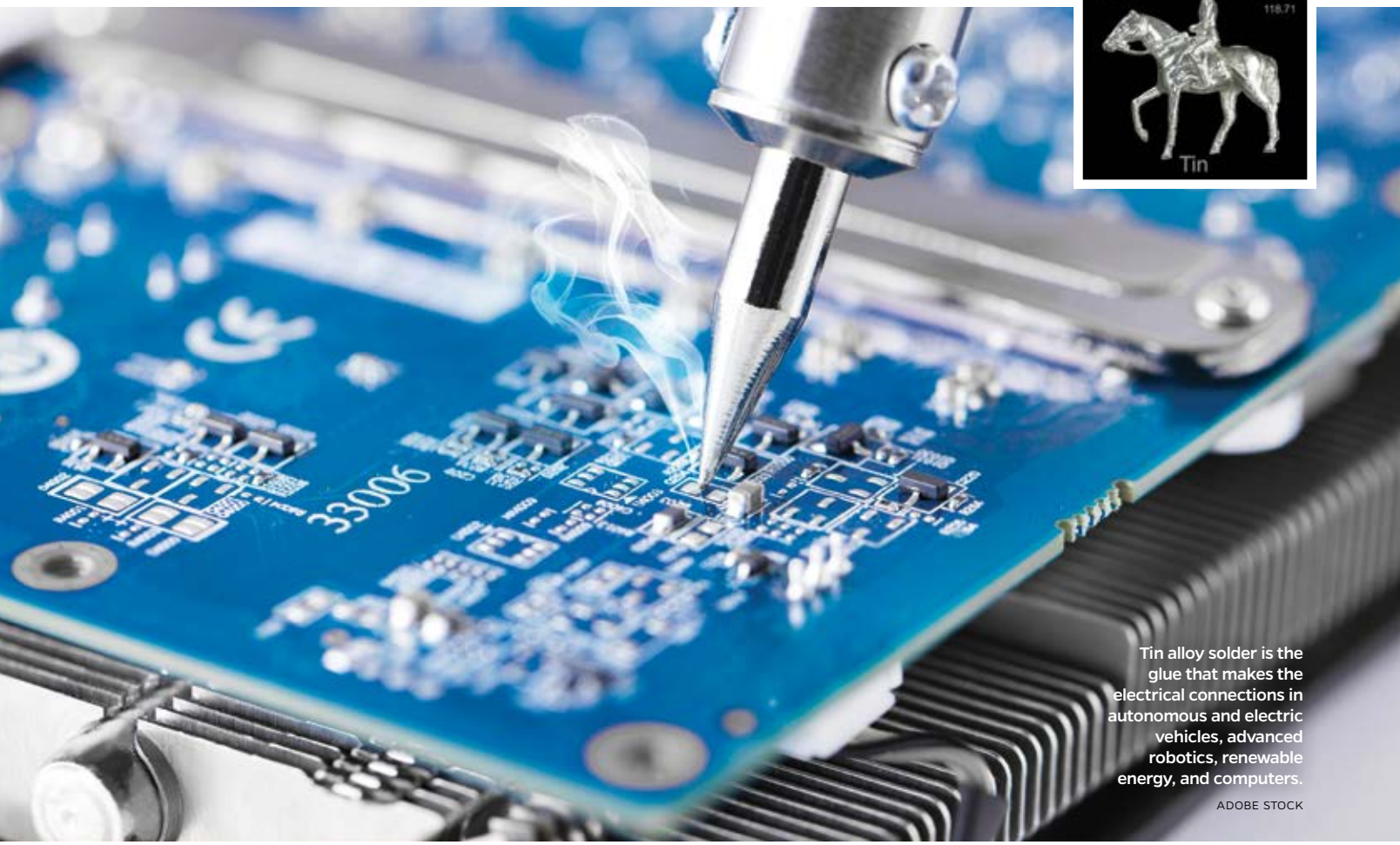
According to a 2019 calculation, Dotson Ridge hosts 4.79 million metric tons of indicated resource averaging 0.6% (31,722 metric tons) rare earth oxides. Though not particularly high-grade, roughly 40% of the rare earths in this deposit are the more highly sought-after heavy REEs, including dysprosium.

This could make Bokan Mountain an intriguing deposit for automakers to look further up the supply chain to secure the raw materials required for the EV revolution.

"Today, automakers from Ford to GM to VW realize that controlling source raw materials right back to the mine could determine how many electric vehicles they will be able to make and at what cost," said Ucore Rare Metals Chairman and CEO Pat Ryan. "The further development of the Bokan Mountain Complex for long term security of rare earth oxides used in powerful electric motors presents an opportunity for deep integration of Western supply chains."

It also provides an opportunity for Alaska to become a valuable link in the global automotive and clean energy supply chains.

"Working together as a team and with our stakeholders, we can help lead the United States' concerted effort to establish an independent REE supply chain to support the transformation to EVs and renewable energy sources and ensure that high-paying family-wage jobs are generated and maintained in Southeast Alaska for decades to come," said Ucore Rare Metals Vice President and COO Mike Schrider. DMN



Tin alloy solder is the glue that makes the electrical connections in autonomous and electric vehicles, advanced robotics, renewable energy, and computers.

ADOBE STOCK

Overlooked tin connects Digital Age

From flashlights to supercomputers, tin is the electrical glue

By SHANE LASLEY
DATA MINE NORTH

LOST IN THE CLAMOR for lithium, nickel and other metals needed for the batteries powering electric vehicles and modern electronics, or the rare earth elements that turn stored energy into motion, is the enormous need for a much more modest metal that is so fundamental to the advancement of technology that it almost goes unseen – tin.

While other technology metals are critical to certain products and sectors of the economy, practically any device with a battery or electrical cord contains tin.

This is because almost half of the tin used in the world today goes into the solder used to make the connections in nearly every electrically powered device imaginable, from the most basic flashlight to the most advanced supercomputer.

A quick look at any printed circuit board will provide a glimpse of how fundamental tin solders are to modern electronics. While on the topside, these mainstays of modern electronics are a mesmerizing metropolis of microchips, transistors, resistors, capacitors, inductors, diodes, and processing units connected by electronic roadways carrying electronic data, a look underneath will reveal a silver-dotted landscape – each shiny dot representing the innumerable electronic connections made with tin alloy solders.

These tiny tin connections are so essential to the Digital Age and beyond that Massachusetts Institute of Technology researchers ranked tin as the metal most likely to be impacted by new technologies such as autonomous and electric vehicles, advanced robotics, renewable energy, and computers.

Roskill, a world-leading metals consultant based in London, agrees with this assessment, and foresees these same technologies finding new uses for the alloying metal.

"Tin's extensive use in solders makes it the metal that glues the technology revolution together, and new applications, such as in emerging lithium-ion batteries, tend to grow as technology advances and diversifies," Roskill wrote.

Cessna 180 fixed-wing aircraft used to carry out new airborne magnetic and radiometric surveys over areas of Montana prospective for rare earth elements, tellurium, tin, and tungsten.

IMAGE COURTESY EDCON-PRJ

Bronze swords to EVs

Whether it be solders gluing together the tech revolution, corrosion-resistant coatings on consumer goods, or the durability it infused into copper during its first rise to criticality during the Bronze Age, tin is nearly always used to bolster the properties of other metals.

"Almost without exception, tin is used as an alloy," the United States Geological Survey penned in the tin section of a comprehensive 2018 report on critical minerals. "The major uses of tin today are for cans and containers, construction materials, transportation materials, and solder."

While these uses provide the foundation for global tin markets, new applications in green technologies could add to the demand for this fundamental metal.

Some consider tin the "forgotten EV metal."

In addition to gluing together the massive maze of circuits in electric cars and trucks, tin is quietly gaining momentum as a performance-enhancing ingredient in the batteries powering these marvels of modern electronics.

In lithium-ion batteries, tin is being considered as an additive to enhance the maximum theoretical capacity of graphite and silicon anodes.

Tin and its alloys are also candidates for anode materials in next-generation rechargeable batteries such as sodium-ion, magnesium-ion, and potassium-ion cells.

Further expanding the frontiers for this fundamental tech metal, researchers have shown tin's potential as a safer and more abundant metal to replace rare and toxic materials used in energy-generating solar technologies, hydrogen production, and fuel cells.

No North American tin mines

As traditional uses and new applications drive up the demand for tin, mining companies and recyclers are struggling to keep pace with the growing demand for this alloying tech metal.

As a result, the price for a pound of tin has climbed from US$7.50 (US16,500 per metric ton) in mid-2020 to as high as US$22 (nearly US$49,000/t) in early March. The price, however, had retreated to around $14.75/lb (US$32,500/t) by mid-year.

Currently, however, there are no tin mines in the U.S. or Canada to reap the benefits from strong prices of this overlooked but essential tech metal.

According to the USGS, the U.S. depended on imports for roughly 78% of its tin during 2021. Indonesia (25%), Peru (22%), Malaysia (19%), and Bolivia (17%) were the top suppliers of refined tin. The balance of the roughly 45,000 metric tons used by American industries last year was recycled from domestic and imported scrap.

"Tin has not been mined or smelted in the United States since 1993 and 1989, respectively," USGS inked in its Mineral Commodity Summaries 2022 publication.

This dependence on foreign sources for new supply and scrap, coupled with the alloying metal's fundamental uses across multiple sectors of the economy, is why tin lands on the list of minerals and metals critical to the U.S.

The two best options for establishing a North American supply to break its dependency on imports for this most critical technology metal are to develop some of the more than 100 tin occurrences identified across Alaska or revisit the past-producing East Kemptville Mine in Nova Scotia.

Global miner Rio Tinto, however, is investigating a third North American option.

Alaska's gateway tech metal

Aside from the geopolitical factors that weigh on U.S. dependency on imports for other critical minerals and metals, the primary reason there are not any North American tin mines is that deposits of this alloying metal are rare in both the U.S. and Canada.

Alaska, which hosts more than 100 known tin occurrences, is considered the best place in the U.S. to establish a domestic source of this long-lived critical metal.

"Today, Alaskan tin deposits are known to be widespread, occurring from the central Alaska Range north to the Brooks Range and across Interior Alaska ... Southwest Alaska and the Seward Peninsula," according to Mineral Deposits of Alaska, a 1997 publication that compiles the work of nearly 50 geologists.

And when it comes to technology minerals exploration in Alaska, tin could be considered the gateway metal due to its direct affiliation with nearly 30 of the 50 metals deemed critical to the U.S.

Beryllium, bismuth, chromium, fluorspar, gallium, indium, manganese, niobium, five platinum group metals, 14 rare earth elements, scandium, strontium, tantalum, tungsten, and vanadium, are among the critical metals and groups of elements associated with the placer and lode tin occurrences across the state.

Most of Alaska's tin occurrences are placer deposits of cassiterite, the primary tin mineral, found across the breadth of the state. This follows a global trend – most of the world's production comes from alluvial deposits rather than the hardrock sources that provide ore for the large-scale production of most minerals.

"Placer deposits have traditionally been an important source of tin; in 2012, they accounted for about 70% of the world output of cassiterite concentrates," USGS penned in its 2018 critical minerals report.

There are a couple of advantages that make placer deposits an intriguing source of tin – Mother Nature has completed the

This pair of bronze swords found in Switzerland were forged roughly 3,000 years ago. The first Bronze Age civilizations to master the ability to alloy tin and copper had a strategic advantage over their counterparts.

LUBOR FERENC; WIKIMEDIA COMMONS

first stage of mineral processing – eroding cassiterite from the hard rock sources and concentrating the tin mineral in deposits that can be mined with simple gravity recovery systems – and these rich sources of Alaska tin are almost always associated with an array of other metals critical to the U.S.

The best-known placer tin regions in Alaska are at Tin City, near the gold rush town of Nome, and the Tofty Tin belt, about 90 miles northwest of Fairbanks.

Placer tin was mined from both these areas early in the 20th century but has had very little modern exploration or production.

In addition to the alluvial deposits, Alaska hosts hardrock tin deposits, including one associated with the Tin City placers.

"One of the few primary hard-rock tin deposits in the United States is the Lost River tin-tungsten-fluorine deposit in the Seward Peninsula, Alaska," the USGS wrote in its 2018 critical minerals report.

Other Alaska hardrock tin deposits include Kougarok, which is located about 90 miles east of Tin City; Sleitat Mountain, found in Southwest Alaska; and Coal Creek, a tin-silver-lithium deposit about mid-way between Anchorage and Fairbanks.

Work in the 1980s estimated a portion of the tin-bearing granites there hosts some six million lb of tin in 240,000 tons of historical resource averaging 1.3% tin. Some of the cassiterite deposits at Kougarok also host considerable amounts of critical metals beryllium, tungsten, fluorspar, niobium, and tantalum.

When it comes to hardrock sources of tin in Alaska, the Coal Creek prospect on Discovery Alaska Ltd.'s Chulitna project roughly midway between Fairbanks and Anchorage shows great promise due to its proximity to rail and grid power, which is a narrow band in the Last Frontier state.

Drilling in the 1980s outlined a historical deposit with roughly 4.8 million metric tons averaging 0.27% (roughly 28.6 million lb) tin, along with silver and zinc.

A 2022 reanalysis of core from the historical drilling at Coal Creek has identified lithium associated with the tin.

Discovery Alaska, an Australia-based mineral explorer, says its initial scan detected lithium across broad zones in all twelve holes.

"The company is excited to identify the first lithium prospect in Alaska, with access to extensive historic drill core that will allow us to rapidly expedite exploration works at Coal Creek, and in a strategic location close to the major Parks Highway and the state-owned Alaska railroad," said Discovery Alaska Director Jerko Zuvela.

These lithium-bearing zones are also prospective for tantalum, niobium, and other critical minerals.

"The company will accelerate works to test the remaining prospective drill core to determine potential scale of the lithium bearing zone," Zuvela added.

Revisiting East Kemptville

The best place in Canada to look for tin is Nova Scotia, where Avalon Advanced Materials is considering the economics of re-establishing a tin mine at East Kemptville, which was operated by Rio Algom from 1985 until 1992.

Avalon, which entered into an agreement for limited surface access to East Kemptville in 2014, has completed limited drilling to affirm the historical resources. Based on this drilling, the company has outlined 22.97 million metric tons of measured and indicated resources averaging 0.153% (roughly 77.5 million lb) tin, and 14.25 million metric tons of inferred resource averaging 0.139% (roughly 43.7 million lb) tin.

> >> *"Tin has not been mined or smelted in the United States since 1993 and 1989, respectively."*
>
> *–United States Geological Survey*

While this resource is substantial, Avalon's immediate interest is in the tailings and ore stockpiled on the property.

The company says that only about half the tin and none of the copper, zinc, and other metals were recovered during the early years of previous operations at East Kemptville.

Much like Coal Creek in Alaska, the tin-bearing rocks on this Nova Scotia property also contain significant lithium, with the potential for indium, gallium, and germanium.

Avalon proposes using ore-sorting technology to recover the high concentrations of critical and base metals contained in the ore stockpiles at East Kemptville. By doing so, the company would be remediating the old mine site while producing metals needed for modern technologies.

In 2018, Avalon published a preliminary economic assessment outlining its tin-producing rehabilitation plans for East Kemptville.

"Avalon strives to be a leader in adopting sustainability best practices and innovative project designs," Mark Wiseman, a sustainability consultant to Avalon, said at the time. "This approach will create an early revenue stream and a platform for growth, while providing a solution for the long-term environmental liability on site."

The company says it is in discussions with several parties interested in new sources of supply of tin concentrate or interested in tin development opportunities. The East Kemptville project, however, is currently inactive until Avalon secures full surface rights to the property.

Third option – Montana

While revisiting East Kemptville or unlocking the potential of more than 100 tin occurrences across Alaska are currently the best options for North American supplies of tin, Rio Tinto believes there may be a third option – Montana.

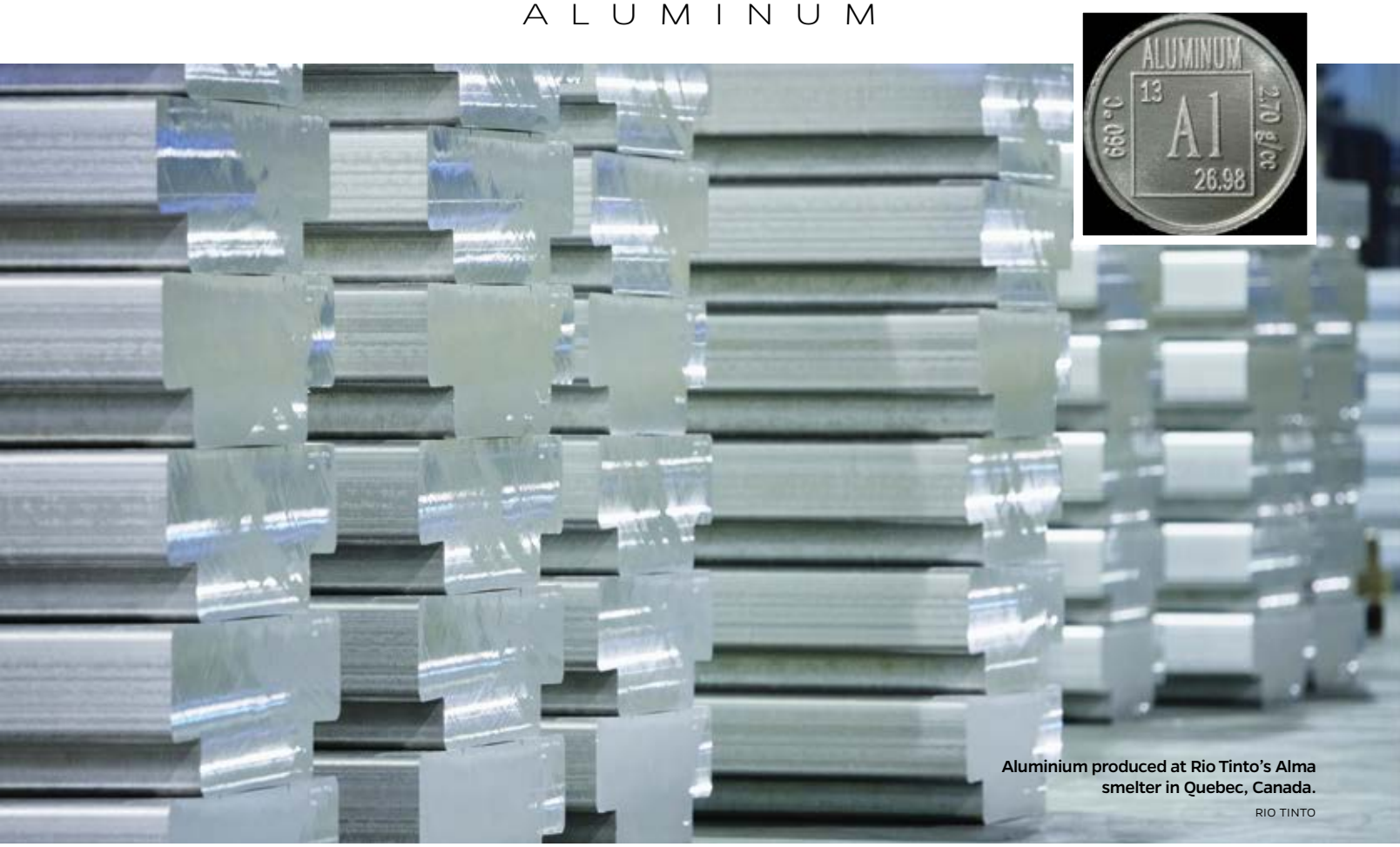
Toward the end of 2021, the global mining company partnered with the USGS to survey an area of southwestern Montana highly prospective for rare earths, tellurium, tin, tungsten, copper, molybdenum, and gold.

To further explore this potential, Rio Tinto is providing support to airborne magnetic and radiometric surveys being carried out as part of the USGS' Earth Mapping Resources Initiative (Earth MRI), a nationwide program to enhance domestic mineral supplies and decrease America's heavy reliance on foreign sources of minerals that are fundamental to economic and national security.

This marks the first partnership between a mining company and Earth MRI.

"By working together, we are sharing expertise, resources, and knowledge to make the search for critical minerals more efficient," said Rio Tinto Exploration Director Chris Welton.

The Earth MRI data collected through this partnership will be available to the public. DMN



Aluminium produced at Rio Tinto's Alma smelter in Quebec, Canada.
RIO TINTO

Underdog aluminum is critical metal too

Shining a light on a metal used in nearly all sectors of today

By A.J. ROAN
DATA MINE NORTH

USED IN EVERYTHING from beer cans to spacecraft, aluminum is a metal most people interact with nearly every day. What many people don't know is this lightweight metal is also a candidate for next-generation rechargeable batteries with the potential to outperform the lithium-ion cells in use today.

The major uses for aluminum metal are generally found in:

• Transportation – automobiles, aircraft, trucks, railway cars, marine vessels, bicycles, spacecraft, etc., often chosen for its low density.

• Packaging – canning, foils, frame, etc., because it is non-toxic.

• Building and construction – windows, doors, siding, building wire, sheathing, roofing, etc. Although steel is cheaper, aluminum is chosen when lightness, corrosion resistance, or engineering features are important.

• Electricity-related uses – conductor alloys, motors, generators, transformers, capacitors, etc. Aluminum is relatively cheap, highly conductive, has adequate mechanical strength and low density, and is resistant to corrosion.

• A plethora of household items – from cooking utensils to furniture. Low density, appealing appearance, ease of fabrication, unlikeliness to spontaneously combust, and mechanical strength make it ideal in many consumer goods.

• Machinery and equipment – processing equipment, pipes, tools, etc., for many of the same reasons as above.

Despite global production of aluminum reaching almost 70 million metric tons in 2021, making it one of the highest produced metals in the world, this versatile metal has a place as one of the United States' 50 critical minerals due to its importance in the aerospace, defense, energy, and transportation industries.

"The United States is a deficit market for aluminum, meaning it consumes more of the metal than it is able to produce domestically.

Consequently, most of U.S. aluminum industry jobs rely in some way on reliable international supply chains," Aluminum Association President and CEO Charles Johnson testified before the U.S. International Trade Commission in July. "I'm happy to report that the U.S. aluminum industry is globally competitive and growing. However, the industry has faced a distorted global market in recent years driven primarily by massive growth in government-subsidized and state-owned aluminum production in China."

A massive bauxite residue (red mud) holding facility outside of Stade, Germany, is one of many such locations throughout the world.

WIKIMEDIA COMMONS

A brief history of aluminum

The history of aluminum has been shaped by the usage of alum – a type of chemical compound, usually a hydrated double sulfate salt of aluminum and potassium used in medicinal solutions as well as dyeing and tanning – with the first written record of alum being made by Greek historian Herodotus dating back to the 5th century BCE.

The ancients were known to have used alum as a dyeing mordant, basically an adhesive to set color into fabric, as well as for city defenses.

After the crusades, alum had become an indispensable good in the European fabric industry and was the subject of international commerce, generally imported from the eastern Mediterranean until the mid-15th century.

While early chemists were eventually able to classify alum as its own substance – as it was often mistaken with other astringents like green vitriol or ferrous sulfate, attempts to produce aluminum metal would not occur until 1760, with the first successful attempt being completed over 50 years later in 1824 by Danish physicist and chemist Hans Christian Ørsted—by combining aluminum chloride and potassium amalgam, it yielded a lump of metal similar in appearance to tin.

Three years later, a German chemist named Friedrich Wöhler attempted to repeat Ørsted's experiments but was unable to produce or identify aluminum.

However, he did not give up and today is credited with being the first to thoroughly describe the metallic element aluminum as well as the discoverer of aluminum itself.

As Wöhler's method could not yield great quantities of aluminum, the metal remained rare, with its cost even exceeding that of gold. Thus, the first industrial large-scale production method would not come into inception until 1886; something called the Hall-Héroult process after French engineer Paul Héroult and American engineer Charles Martin Hall.

It was roughly 10 years later that Austrian chemist Carl Joseph Bayer discovered a way of purifying bauxite to yield alumina, now known as the Bayer process.

Both methods are still predominately used, with many aluminum producers transforming bauxite to alumina and then alumina to aluminum.

From bauxite to aluminum

Before being transformed into its well-known and lightweight metallic form, the Bayer process of making aluminum starts by drying crushed or washed bauxite which is then dissolved in caustic soda to form a slurry and then heated. This mixture is then filtered to remove the residue or what is commonly referred to as red mud.

The filtered solution is then transferred or pumped into precipitator tanks, where it cools and starts to seed. These seeds stimulate a precipitation process allowing solid aluminum hydroxide crystals to form.

After completion, all the aluminum hydroxide that settles at the bottom of the tanks is removed.

The remaining caustic soda is washed away from the aluminum hydroxide, which undergoes further levels of filtering and then finally heated once more to remove any excess water. After passing through a cooling stage, a fine white powder remains – aluminum oxide or alumina.

Bauxite residue, commonly referred to as red mud due to its color and consistency, is a waste material produced during the aluminum-making process that is typically stored in large containment facilities. This discarded waste material, however, has emerged as a potential alternative source of critical minerals.

■ *More information on recovering critical minerals from bauxite residue and other alternative sources can be read at* ***Outside-the-box critical mineral sources*** *on page 70.*

While a great majority of aluminum oxide produced with the Bayer process is converted to metal, aluminum compounds have many niche applications such as:

- Aluminum acetate in solution is used as an astringent to treat wounds.
- Aluminum phosphate is used in the manufacture of glass, ceramic, pulp and paper products, cosmetics, paints, varnishes and even dental cement.
- Aluminum hydroxide by itself is used as an antacid, as well as a dyeing binder, more specifically called a mordant. Aluminum hydroxide is also used in water purification, as well as other glass and ceramic products and the waterproofing of fabrics.
- Lithium aluminum hydride is a powerful reducing agent used in organic chemistry.
- Aqueous aluminum sulfate is used to treat against fish parasites commonly known as salmon fluke.
- Certain aluminum salts serve as an immune adjuvant or immune response booster in vaccinations.
- And many more uses, generally in advanced chemistry processes.

With such widespread usage, it is no small wonder it has become critical to the U.S. While concerns over supply chains being vulnerable to disruption are currently at the forefront of headlines everywhere, as the second-highest produced metal in the

world, aluminum is not going anywhere, anytime soon.

Aluminum-graphene batteries

While aluminum is an excellent electric conductor, it is generally passed over for more resilient metals that require less preparation and provide better longevity in electricity-using industries.

One function, however, that is not well known is that aluminum has the potential to be a better base material for rechargeable batteries than lithium. This is due to aluminum's ability to exchange three electrons for every ion, compared to a single ion for lithium – enabling up to three times more energy density.

While scientists have long been searching for an alternative to the expensive and limiting lithium battery, previous iterations continue to use graphite as the primary cathode material, "which has too low an energy content to create battery cells with enough performance to be useful," according to some researchers.

That is until graphene entered the equation.

As graphene manufacturing has seen explosive growth in recent years – production facilities being able to scale up production of this 2D form of carbon and new and exciting innovations contributing to its widespread use – researchers and manufacturers have taken to the miracle material like bees to honey.

Graphene Manufacturing Group, an Australian-based clean-tech company that produces graphene and hydrogen by cracking methane instead of mining graphite, is incorporating a technology devised by the University of Queensland's Australian Institute of Bioengineering and Nanotechnology (AIBN) and the university's commercialization company Uniquest, to unlock the potential of graphene aluminum-ion batteries.

At the latter end of 2021, GMG announced that its pilot production and testing plant for its graphene aluminum-ion batteries is now operational, with the first coin cells being manufactured.

According to GMG, laboratory testing and experiments have shown so far that the graphene-aluminum-ion battery energy storage technology has high energy densities and higher power densities compared to current leading marketplace lithium-ion battery technology.

Specifications detailed by the company include a power density of up to 7,000 watts per kilogram, with testing confirming a cycle rate with minimal reduction over a 3,000-cycle experiment period

GMG

A graphene aluminum-ion battery could be the replacement to lithium-ion batteries the world has been waiting for.

– which included charging up to full charge and discharging down to near full discharge – at variable charging rates.

The company also said these results showed a very high cycling rate for the duration, with negligible reduction in performance and at a very high charging rate of up to 66 coulombs (amperes per second), which is comparable to lithium-ion batteries between 600 to 1,000 cycles at much lower charging rates of one-fifth coulombs, where performance typically reduces to 60% of original capacity.

In layman, this means a much longer battery charge, immensely shorter recharge time, and a significantly longer life span.

"Testing showed rechargeable graphene aluminium-ion batteries had a battery life of up to three times that of current leading lithium-ion batteries, and higher power density meant they charged up to 70 times faster," said University of Queensland AIBN Director Alan Rowan. "The batteries are rechargeable for a larger number of cycles without deteriorating performance and are easier to recycle, reducing potential for harmful metals to leak into the environment."

With the possibilities that graphene presents, aluminum may see a monumental jump in its critical status, and according to GMG CEO Craig Nicol, "It is the technology the industry has been waiting for." DMN

RIO TINTO

Rows of aluminum ingots from New Zealand's Aluminium Smelter, a jointly owned venture by Rio Tinto (79.36%) and Sumitomo Chemical Company (20.64%) that will run until 2024.

A satellite view of a coal ash landfill near the closed Mitchell Power Plant in Pennsylvania.
GOOGLE EARTH

Outside-the-box critical mineral sources

Coal ash, acid drainage, and tailings for future green economy

By A.J. ROAN
DATA MINE NORTH

AS THE WORLD CONTINUES to prime itself for the global energy shift, academia, governments and the private sector are scrambling to extract the valuable minerals and metals necessary to power the low-carbon renewable future – resulting in some truly innovative and unconventional methods.

In addition to the rare earths, cobalt, lithium, and other technology metals that capture headline attention, this list often misses the more obscure mined materials such as gallium, germanium, scandium, and tellurium.

While scarce, these critical elements are often found alongside more common minerals and metals such as aluminum, coal, copper, and zinc.

The green transition is driving staggering new demand for these previously little used critical minerals and metals.

To combat a looming scarcity, groundbreaking technologies have begun to spring up to sift through the remnants left behind from more than a century of powering America with coal, the tailings of yesterday's metal mines, and the acid mine drainage created when water and air oxidize sulfide-rich rocks, offer potential unconventional domestic sources of the equally unconventional metals needed to build tomorrow's technologies.

Win-win in coal country

The Biden administration believes that extracting the critical minerals left behind by historical mining and coal-fired electricity generation offers multiple layers of benefits to the U.S. – new domestic sources of the minerals and metals vital to America's climate goals and technology industries; an opportunity to clean up legacy mine waste with modern technologies, and under modern environmental law; and the creation of new economic opportunities in regions that have traditionally delivered the coal that

powered much of America's homes and industries for more than a century.

"Applying next-generation technology to convert legacy fossil fuel waste into a domestic source of critical minerals needed to strengthen our supply chains is a win-win – delivering a healthier environment and driving us forward to our clean energy goals," said U.S. Secretary of Energy Jennifer Granholm.

Toward this altruistic goal, the $1 trillion Infrastructure Investment and Jobs Act includes $140 million to support the design and development of a refinery to demonstrate the commercial viability of extracting rare earths and critical minerals from unconventional resources and separating and refining them into the metals being demanded by American industries.

"With the Bipartisan Infrastructure Law's investment in the build out of this first-of-its-kind critical minerals refinery, we are moving ideas from the lab to the commercial stage and demonstrating how America can compete for the global supply chain to meet the growing demand for clean energy technology," the Energy Secretary added.

To put the best ideas and technologies into this critical demonstration refinery, DOE invited input from industry, investors, developers, academia, research laboratories, government agencies, non-governmental organizations, and communities that potentially could be affected by the development of the critical minerals plant.

DOE sought feedback on demonstration facility features, supply chain considerations, research and development needs, business models, and potential societal impacts and benefits of the proposed critical minerals extraction and separation facility.

While the energy department encourages outside-of-the-box thinking when it comes to unconventional sources of critical minerals, it does not want to stray too far from convention when it comes to the technologies that will be used to extract and refine these technology metals.

The energy department envisions that this first-generation separation facility will use proven methods such as hydrometallurgy and solvent extraction for the separation of individual rare earth and critical mineral oxides, as well as the subsequent refining and alloying of metals.

"Further advanced technologies will be encouraged, but only if tested and ready to be applied at demonstration scale," DOE inked in its request for information.

Acid mine drainage occurs when mining exposes sulfide-containing minerals, which react with air and water to form sulfuric acid.

NATIONAL SCIENCE FOUNDATION

Phoenix arises from tailings

The tailings left behind from mining aluminum, copper, gold, silver, zinc, and other more common metals offer another potential unconventional source of critical minerals while also chalking up a win for the environment.

Mining is an energy-intensive industrial process that typically involves crushing massive quantities of rock dug from the earth into a sand- or silt-like consistency to extract the minerals and metals needed by society. The leftovers from this process, called tailings, are typically stored in a facility until the mine closes and then covered up and contoured during the mine reclamation process.

Critical minerals such as cobalt, germanium, rare earths, tellurium, and titanium are often thrown out with the tailings. In the past, the market was not large enough to justify extracting most of these minor elements, or the cost of the extra steps was too great.

With modern solar panels, EVs, lithium-ion batteries, and other innovative technologies creating new demand for these metals, companies are beginning to look at tailings storage facilities as critical mineral ore deposits – Phoenix Tailings is one such company.

"We want to get to the point where there is no such thing as 'waste' and there is only material waiting to be processed into new products," Mike Martin, an engineer, material scientist, and co-founder of Phoenix Tailings, told Jaclyn Severance at the University of Connecticut. "To put it another way, we want to show people tailings ponds are a huge untapped opportunity."

One of the advantages of tapping this opportunity is most of the heavy lifting has already been done – the rock has been mined and crushed.

With these energy-intensive and costly steps out of the way, a company like Phoenix only has to focus on the most efficient and sustainable methods for recovering whatever critical minerals might be in the cast-off material.

Using three separate processes – hydrometallurgy, solvometallurgy, and electrometallurgy – Phoenix has the ability to tailor its extraction systems to the tailings and minerals being targeted.

Much like extracting critical minerals from coal ash and acid mine drainage, the re-mining of tailings offers the added benefit of leveraging liabilities at already industrialized sites to produce the unconventional metals needed to build a cleaner and greener future.

Geomega reduction in aluminum waste

While still wholly capable of recovering rare earths from recycled magnets and potential ore, Geomega Resources Inc.'s rare earths and critical minerals extraction technology may draw value from and reduce the environmental footprint of bauxite residues piling up at aluminum refineries.

Commonly referred to as red mud, a reference to the color and consistency of this waste material, bauxite residues are typically stored in large containment facilities. The large quantities of this ofttimes caustic red mud have led

The Biden administration believes that extracting the critical minerals left behind by historical mining and coal-fired electricity generation offers multiple layers of benefits to the U.S.

ADOBE STOCK

researchers and refiners to seek alternative uses for it.

Bauxite residue is a byproduct that is generated during the refining of alumina. Geomega's core project is based around its Innord's Separation of Rare Earths (ISR) technology, a proprietary, low-cost, and environmentally friendly way to tap into the C$1.5 billion global market to recycle magnet production waste and end-of-life magnets.

Innord, a subsidiary of Geomega, has been tasked with developing solutions to large industrial mine waste challenges with its technology to extract critical minerals. The process has the potential to significantly reduce the quantities of this red mud that would need to be stored at aluminum refineries.

Taking immediate interest in the potential to reduce the discarded waste piles, Rio Tinto, the largest aluminum producer in North America, along with Sustainable Development Technology Canada and the Quebec government, have invested a total of C$5 million to evaluate Innord's technology to potentially monetize the iron compounds produced by Innord's Bauxite Residues Technology (IBRT).

"Bauxite residue, the waste generated from aluminum production, requires significant management and monitoring from mining companies to avoid environmental impacts," said Sustainable Development Technology Canada CEO Leah Lawrence. "Innord Inc. is developing a process that reduces the volume of red mud by 70-90% while recovering valuable minerals from that waste."

This has the potential to create a new value stream for Rio Tinto, reduce the financial and environmental liabilities associated with storing the red mud, and extend the life of alumina operations without the need to build additional storage.

For Geomega, this offers a way to scale up and generate revenue from a technology with the potential to transform costly waste products into valuable metals.

With more than 4 billion metric tons of red mud stored in facilities around the world, there is no shortage of material for a commercial version of Innord's bauxite residue technology.

REEs from the ashes of coal mining

Aside from the obvious motivation of giant companies seeking to squeeze value from every stone it digs up, government research facilities, universities and private labs are inching along in the pursuit of clever and unique ways to tap into not only waste but new chemistries involving REE separation and recovery.

One such resource, a mainstay as the focal point of energy production before petroleum began to dominate, was coal.

A compelling source for the rare earths needed for electric vehicle motors, wind turbines, and an array of high-tech digital devices is the ash left behind by more than a century of burning coal to generate electricity in America.

"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 the US transitions to lower-carbon energy sources, more than 100 years

■ *You can read about Round Top and Texas Mineral Resources at* ***Making rare earths separation less rare*** *on page 54.*

of coal-fired electrical generation has created a glut of this REE-enriched waste product – billion of tons of it.

Best known for its contribution to advancing the Round Top rare earths and critical minerals mine project, Texas Mineral Resources Corp. has been leading a group targeting the development of a mine capable of recovering rare earths from Pennsylvania coal byproducts.

The Texas-based mineral explorer teamed up with Penn State University; Jeddo Coal Company, a family-run mining company with an operation in Pennsylvania; and H22OS Consulting, an engineering and construction firm that specializes in mining.

With added support from the Department of Energy, the consortium hopes to use an advanced extraction method Penn State developed to extract rare earths from coal byproducts.

This advanced extraction method, which uses continuous ion exchange and continuous ion chromatography (CIX-CIC), is the same technology being developed to extract rare earths and other critical minerals from concentrates from a future mine at the Round Top project in Texas and is also the focus of Texas Mineral's funding partner, USA Rare Earth's pilot plant in Colorado.

Value from acid mine drainage

But coal is not the only waste product from mining that scientists are seeking to recycle. Once again, Pennsylvania State University focused its attention on another aspect that damages the environment and leaves miners scratching their heads – acid mine drainage.

Acid mine drainage occurs when mining exposes sulfide-containing minerals, which react with air and water to form sulfuric acid.

While this process sometimes occurs naturally, it can be more pronounced after mining if the exposed sulfides are not cut off from sources of water and air. The acidic runoff from such mines often carries excessive quantities of metals, many of which are toxic to plants and wildlife.

Hence, the university developed a process that could transform acid mine drainage from an environmental liability that is costly, to an asset that produces rare earths and other valuable minerals.

"Acid mine drainage has been a significant environmental concern for many decades," said Mohammad Rezaee, assistant professor of mining engineering in the College of Earth and Mineral Sciences at Penn State.

Thus, Rezaee and his colleagues have developed a two-stage treatment process that can recover more of the metals out of acid mine drainage while using fewer chemicals than earlier techniques.

"This research shows we can modify existing treatment processes in a way that not only addresses environmental concerns, but at the same time recovers valuable elements and actually decreases the cost of treatment," Rezaee added.

The traditional process involves collecting acid mine drainage in ponds and adding chemicals to neutralize the pH, which causes the dissolved metals to solidify and drop out of the water. The Penn State researchers said that about 70% of rare earths could be extracted as sludge using this process.

This could provide a valuable domestic source of these rare earths used in an increasing number of high-tech, renewable energy and other applications.

"This technique represents an efficient, low-cost and environmentally friendly method to extract these valuable minerals that are used in a wide variety of consumer and industrial products," said Pisupati, who is also director of the Center for Critical Minerals at Penn State.

By first injecting carbon dioxide into acid mine drainage, a process that produces a carbon mineral called carbonatites, the Penn State team found it could recover more metals at higher pH values. This is because rare earths and other metals latch onto the carbonatites and more readily settle out of the water.

While transforming carbon dioxide into rocks is an emerging technique for removing carbon dioxide from the atmosphere, the Penn State research is the first time carbon dioxide mineralization has been applied to treating acid mine drainage.

"With a simple modification of existing treatment processes, industry could use less chemicals and get more value out of AMD waste," Rezaee said. "This is the beauty of this research." DMN

The 163-megawatt Elm Branch solar project in Texas was developed by Lightsource bp and is powered by First Solar's cadmium-tellurium thin-film photovoltaic solar panels.

LIGHTSOURCE BP

First Solar powers new tellurium demand

Rare metalloid key element of CdTe thin-film solar cell tech

By SHANE LASLEY
DATA MINE NORTH

THE RISING POPULARITY of thin-film solar cells as a highly effective means of converting sunlight into electricity is creating increased demand for tellurium, amongst the rarest of the stable elements on the periodic table.

Tellurium is a metalloid, one of seven elements with properties that fall between metals like aluminum and tin and non-metals like carbon and phosphorus. These semimetals, which also include silicon and germanium, have natural semiconductive qualities that make them ideal ingredients for photovoltaic solar cells.

While silicon remains the dominant metalloid used in the production of photovoltaic solar cells, cadmium-telluride (CdTe) thin-film cells are a rising star when it comes to harnessing sunlight to fill the world's growing needs for low-carbon electricity.

"Cadmium telluride solar cells have the characteristics of strong power generation capacity, high conversion rate, low temperature coefficient, good weak light effect and high stability," 360 Research Reports penned in a CdTe thin-film solar cell market report.

These characteristics have piqued the interest of the U.S. Department of Energy, which is supporting research focused on overcoming the current technological and commercial barriers for CdTe cells.

According to the 360 Research report, the CdTe solar cell market is expected to top $10 billion in 2027, which is more than double the roughly $4 billion of these thin-film PV cells installed in 2021.

This growth is expected to power up demand for the extremely rare tellurium.

"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," according to the United States

Geological Survey.

While tellurium may be one of the scarcest of the elements, this solar-absorbing metalloid often hitches a ride with concentrates produced at copper mines and can be recovered at the refinery.

This has global production of the thin-film solar metalloid closely tied to copper.

"The main concern surrounding tellurium supply is the question of whether or not global copper production can meet the growth in tellurium demand," USGS penned in a 2014 tellurium brochure.

Fortunately, the same low-carbon energy push that is increasing the demand for more solar panels, and the tellurium that goes into the thin-film versions, is also powering the demand for the copper that links the solar panels together and then to the grid, creating the potential for tandem increase in production of these green energy elements.

Solar-powered demand

Traditionally, tellurium was used as an additive to improve the strength and pliability of steel, copper, and lead alloys. In recent years, solar and other technological applications have dominated the demand for this uncommon metalloid.

USGS estimates about 40% of the tellurium consumed in the U.S. during 2021 went into the production of cadmium-tellurium photovoltaic cells and 30% went into the production of bismuth-telluride thermoelectric devices for cooling and energy generation. The balance of this rare metalloid used in America went into alloying additives to improve the machining characteristics of steel and as a vulcanizing agent and accelerator in the processing of rubber.

While one refinery in Texas ships copper anode slimes to Mexico to recover the tellurium, the U.S. is dependent on imports for 95% of this critical metalloid.

Like many of the critical metals (and metalloids), China dominates tellurium production, accounting for nearly 60% of the roughly 580 metric tons of tellurium recovered globally during 2021.

The U.S., however, was able to source about 57% of its 2021 tellurium needs from Canada, with most of the remaining balance coming from Germany, China, and the Philippines.

Driven largely by Ohio-based First Solar Inc., the world's largest CdTe solar panel manufacturer, the popularity of thin-film solar panels and the tellurium that goes into them is expected to grow as the technology matures.

"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, lab director at DOE's National Renewable Energy Laboratory.

In early April, First Solar landed three contracts for the installation of 5 gigawatts of its CdTe solar modules to be installed by 2025.

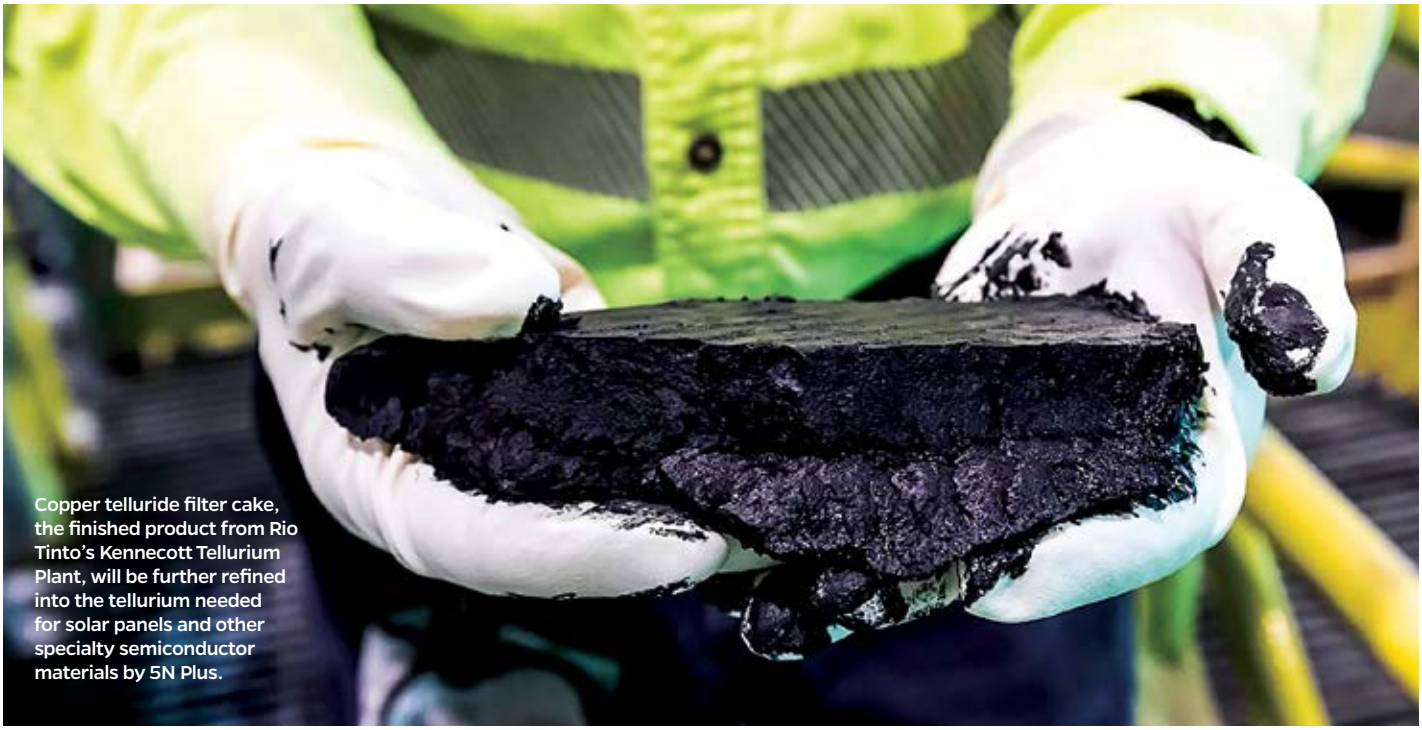
All three companies touted First Solar's U.S. production, cutting-edge solar technology, and leadership in sustainability.

"By partnering with First Solar we also found an innovator that can deliver high performance solar panels with the lowest carbon footprint and the best environmental profile available today," Nevada Gold Mines Executive Managing Director Greg Walker said when the Barrick Gold and Newmont joint venture ordered solar panels for the largest gold-producing complex in the world.

This environmental profile includes a recycling program that recovers approximately 90% of the cadmium and tellurium material from old thin-film solar panels, which can then be used to manufacture new modules. Aluminum, glass, and laminates are also recycled for other products.

Considering that First Solar's latest series of thin-film cells are expected to retain at least 92% of original performance at the end of their 30-year warranty, recycling these panels may not be a significant source of tellurium in the near term.

To date, First Solar has invested over $2 billion in its U.S. manufacturing footprint and, when its third factory is fully operational, will directly employ approximately 2,500 people in



RIO TINTO

Copper telluride filter cake, the finished product from Rio Tinto's Kennecott Tellurium Plant, will be further refined into the tellurium needed for solar panels and other specialty semiconductor materials by 5N Plus.

Ohio, while supporting an estimated 7,000 indirect jobs through its American supply chain.

A supply chain that is going to need increasing quantities of tellurium fed into it.

Rio Tinto steps up

Seeing the growing need for domestic supplies of tellurium, Rio Tinto invested approximately $2.9 million to build a plant capable of recovering roughly 20 metric tons of this semiconductive metalloid as a byproduct of the copper produced at its Kennecott Mine in Utah.

"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 Chief Operating Officer Clayton Walker said upon the start up of this facility earlier this year.

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

Rio Tinto says First Solar will be the primary customer for the tellurium now being produced at its world-class copper mine in Utah.

"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."

5N Plus will also use Kennecott tellurium to manufacture ultra-high purity semiconductor materials at its facility in Utah.

With the addition of tellurium, Rio Tinto now produces 10 mined commodities at Kennecott. In addition to accounting for nearly 15% of the mined copper in the U.S., this Utah operation recovers gold, silver, lead carbonate, platinum, palladium, and selenium.

"Utah continues to play a key role in domestic production of critical minerals," said Utah Governor Spencer Cox. "With operations in our state like Rio Tinto Kennecott, we are able to demonstrate to the world how to responsibly make use of our natural resources to move toward a sustainable future."

First Solar said tellurium from Kennecott will likely supplement its current supplies coming from the U.S., Canada, and Europe.

A tellurium gold mine

If copper refineries and recycling cannot keep pace with tellurium's solar-powered demand, there is another option – gold mines.

"Recycling solar cells may help, but tellurium-rich films have long lifespans and to date have not been extensively reused. It might become an economic necessity to extract tellurium directly from telluride minerals during gold mining in locations such as Cripple Creek, Colorado; the Sierra Foothills of California; and southeastern Alaska," USGS wrote.

About a decade ago, First Solar considered mining its own tellurium from the Klondike gold-silver project about 100 miles northeast of Durango, Colorado. When the company decided to forego its own tellurium mining venture, First Tellurium Corp. 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."

Early in 2022, Keller collected additional samples in preparation for a drill program at Klondike. One of the rocks collected during this sampling contained 1.1% tellurium, 3.76 g/t gold, and 130 g/t silver, along with copper, zinc, and lead.

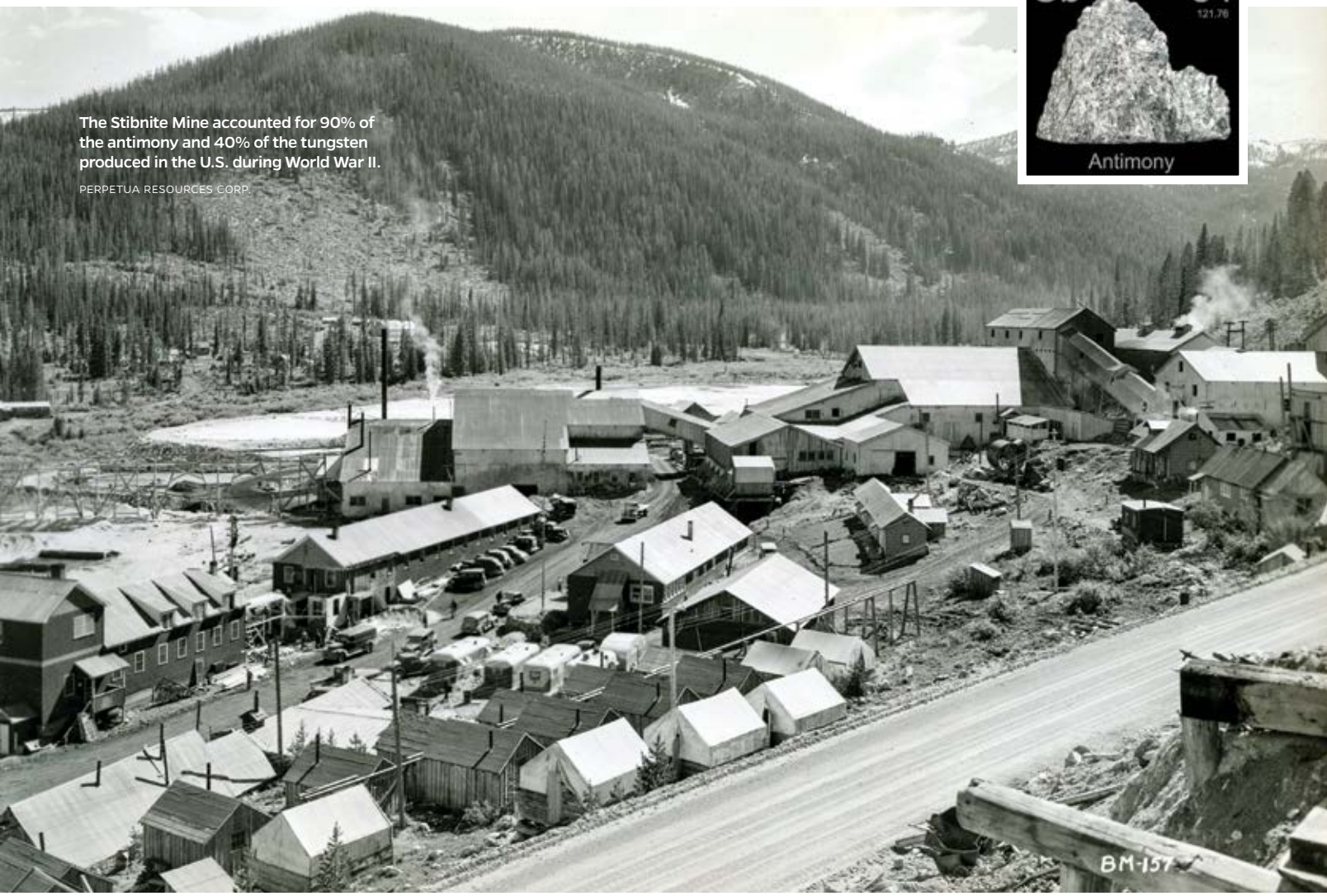
"We knew from First Solar's work that Klondike was a prime tellurium property," said First Tellurium CEO Tyrone Docherty. "These results provide a solid launch point for further exploration in 2022."

The Juneau Gold Belt of Southeast Alaska, the Kirkland Lake and Red Lake districts of Ontario, and the Yellowknife Mining District in Northwest Territories are other gold mining areas in North America particularly enriched in tellurium.

Recovering this solar metalloid from precious metals deposits, however, would require new processes.

"Tellurium concentrations are highest in precious-metal-bearing deposits that contain abundant telluride minerals; these deposits, however, currently are not significant sources of tellurium because the ore-processing method to extract gold and silver is not amenable to tellurium recovery," the USGS reported in a 2018 report.

As thin-film CdTe solar panels gain in popularity, precious metal miners might join the ranks of copper refineries in providing byproduct supplies of this critical metalloid that efficiently converts sunlight into electricity. DMN



The Stibnite Mine accounted for 90% of the antimony and 40% of the tungsten produced in the U.S. during World War II.

PERPETUA RESOURCES CORP.

Antimony at top of strategic concerns

Russia, China control of global supplies worry DC lawmakers

By SHANE LASLEY
DATA MINE NORTH

FROM ITS USES IN FLAME RETARDANTS that have saved countless American lives to being an important ingredient in batteries poised to be the answer to the challenge of storing intermittent renewable energy, few metals are more critical to the national security and economic wellbeing of the United States than antimony.

Described as a metalloid, which means it falls somewhere between metals such as zinc and solid nonmetals like sulfur, antimony possesses some interesting properties that make it an important ingredient in products that span a wide range of industrial sectors – from textiles to high-tech.

On the textile front, antimony is utilized in compounds used in fireproof fabrics that can be found in every walk of life, from battlefields and industrial workplaces to baby nurseries and personal autos.

Antimony is also used to make high-quality glass utilized by both civilians and soldiers. For example, a small amount of antimony oxide has the ability to remove bubbles and make super-clear glass for binocular lenses and similar optical equipment, as well as the glass screens of smartphones and other electronic devices.

The biggest single use for this critical metalloid, however, is in improving plate strength and charging characteristics of the lead-acid batteries that have been used to start most internal combustion engine vehicles for more than a century.

The antimonial lead that goes in everyday car batteries and similar alloys are used to make ammunition, bearings, solders, electrical cable sheathing, and radiation shielding.

All these uses make antimony a very strategic metalloid to the U.S. military.

"Antimony is a key ingredient in communication equipment, night vision goggles, explosives, ammunition, nuclear weapons, submarines, warships, optics, laser sighting, and much more," U.S. Army Major General (retired) James "Spider" Marks inked in a 2020 column published in The Washington Times.

In addition to its military uses, antimony is increasingly being used as a primary ingredient in liquid-metal batteries that can store electricity at the grid-scale, a key enabler to the transition to intermittent renewable energy sources.

Despite its strategic value to the Pentagon and critical applications in the private sector, no marketable antimony is being mined in the U.S. Instead, America depends on oft adversarial countries for more than 80% of its needs, with the rest coming from recycling.

According to USGS data, China produced roughly 55% of global supply during 2021, and Russia accounted for about 23%, which comes to a combined 78%.

Even before Russia's invasion of Ukraine, and the related sanctions that likely isolate a sizeable supply of antimony, there was global shortage of the critical metalloid due to environmental audits in China and temporary mine shutdowns to mitigate the spread of COVID-19.

As a result of the supply shortage, antimony was selling for US$6 per pound at mid-year, more than double the US$2.67/lb average price in 2020.

While America does not have any operating antimony mines, it does have some significant deposits of this strategic and critical semimetal found in Idaho, Alaska, Nevada, and Montana.

Ambri liquid-metal batteries have a liquid calcium alloy anode, a molten salt electrolyte, and a cathode comprised of solid particles of antimony. Perpetua Resources will provide antimony for these batteries (pictured at right) from its Stibnite Mine project.

AMBRI INC.

Stockpiling antimony

America's heavy dependence on China and Russia for antimony has Washington, DC lawmakers worried.

In a June 8 National Defense Authorization Act report, the U.S. House Armed Services Committee said it "is concerned about recent geopolitical dynamics with Russia and China and how that could accelerate supply chain disruptions, particularly with antimony."

Due to this concern, the committee has directed the manager of the National Defense Stockpile at the Defense Logistics Agency to provide a briefing on the status of the antimony stockpile and provide a five-year outlook on current and future supply chain vulnerabilities.

The House Defense Appropriations Subcommittee also included $10 million in its bill for the Army to study domestic sourcing and production of military-grade antimony trisulfide for tank and medium caliber ammunition.

The concerns over potential geopolitical consequences of being dependent on China and Russia for antimony and other critical minerals are being echoed by the Senate Armed Services Committee.

"America's defense in the modern era increasingly demands the use of critical minerals, making it more essential by the day for our nation to have a sufficient stockpile of and reliable access to these materials," said Sen. Joni Ernst, R-Iowa, a combat veteran that serves on the Senate Armed Service Committee. "At this very moment, our enemies like China dominate the supply chain of these increasingly vital materials, and are even expanding into regions such as Africa and Afghanistan, threatening our readiness in an emergency situation and jeopardizing our national security." Senators Ernst and Joe Manchin, D-West Virginia, who also serves on the Armed Services Committee, introduced the Homeland Acceleration of Recovering Deposits and Renewing Onshore Critical Keystones (HARD ROCK) act on June 14.

This legislation is designed to bolster the National Defense Stockpile of strategic and critical materials needed for national security.

"America is blessed with an abundance of natural resources that can help us address our reliance on foreign supply chains for critical minerals," said Sen. Manchin, who also serves as chair of the Senate Energy and Natural Resources Committee. "By addressing the weaknesses in our current National Defense Stockpile, our bill will bolster American critical mineral independence and help ensure we have the resources we need for essential defense products and services."

In addition to the HARD ROCK Act, the Senate National Defense Authorization Act includes $1 billion in funding to support the Defense Logistics Agency's acquisition of critical defense materials, like antimony, for the National Defense Stockpile.

One company looking to revive a historic mine in Idaho that provided the U.S. with a strategic supply of antimony during World War II has a six-year head start when it comes to offering a domestic source of this metalloid critical to the nation's defense.

Strategic Stibnite Mine

Many of North America's richest gold

AMBRI INC.

districts also host healthy quantities of stibnite, but the latter antimony mineral is often discarded in favor of the more valuable precious metal. This dynamic, however, reversed at gold mines in Idaho and Alaska when antimony's strategic value increased during the World Wars.

This is particularly true for the Stibnite gold mine in Idaho, which shifted its focus to recovering tungsten and antimony to support the needs of the U.S. military during World War II.

From 1941 to 1945, Stibnite Mine produced more antimony and tungsten than any other mine in the U.S. – accounting for 90% of the antimony and 40% of the domestic tungsten produced during this wartime effort.

This Idaho mine was singlehandedly credited for substantially shortening the duration of World War II, potentially saving millions of lives.

"In the opinion of the munitions board, the discovery of that tungsten at stibnite, Idaho, in 1942 shortened World War II by at least 1 year and saved the lives of a million American soldiers," according to the March 7, 1956 U.S. Senate Congressional Record.

Perpetua Resources Corp. plans to reestablish Stibnite as a domestic source of the antimony that could lessen America's dependence on adversaries for this strategic metalloid.

"I am encouraged by the recognition from the congressional committees with jurisdiction over national security that we simply cannot allow Russia and China to control our country's access to munitions and military equipment," said Perpetua Resources President and CEO Laurel Sayer. "Without immediate action to secure access to the minerals we need, America will continue to be vulnerable. Perpetua's vision for the Stibnite Gold project includes providing our nation with the only domestically mined source of antimony and, in doing so, offers solutions to help strengthen our national defense."

Once Perpetua realizes its vision, the Stibnite mine is expected to supply roughly 35% of America's current antimony needs while also producing roughly 4.24 million ounces of gold over 15 years of mining.

Now roughly six years into the federal permitting process, Perpetua hopes to gain final authorizations to begin the work of building a modern-era Stibnite Mine by early 2024.

Liquid-metal antimony batteries

Once the Stibnite Gold project finally does make its way through the long and arduous U.S. mine permitting process, a portion of the antimony produced there will go into liquid-metal batteries, a new form of large-scale energy storage developed at the Massachusetts Institute of Technology in Cambridge.

The long-duration liquid-metal batteries developed by Ambri Inc., a battery technology company born from research at MIT, are designed to outperform lithium-ion batteries when it comes to cost, longevity, and safety for storing the increasing amounts of renewable energy being integrated into electrical grids.

> >> *"Perpetua's vision for the Stibnite Gold project includes providing our nation with the only domestically mined source of antimony and, in doing so, offers solutions to help strengthen our national defense."*
>
> *–Perpetua Resources CEO Laurel Sayer*

At room temperature, Ambri's cell is non-conductive, and its materials are solid. Once heated to 500 degrees Celsius (932 degrees Fahrenheit), however, the minerals and metals melt and become active. The passing of ions through the electrolyte as the battery charges and discharges keeps the metals molten, eliminating the need for auxiliary heating or cooling.

Basically, these batteries are just one big stainless-steel tank without the need for dividers because, like oil and water, the liquid calcium alloy anode and molten salt electrolyte have different densities and do not mix.

Ambri says these batteries are less expensive to manufacture, work in a wider range of climatic conditions, last longer, need virtually no maintenance, and do not pose the threat of catching fire like their lithium-ion counterparts.

"Our technology will fundamentally change the way power-grids operate, increasing the contribution from renewable resources and reducing the need to build traditional power plants," Ambri says. "Customers will see lower electricity bills and more reliable service."

This adds to the criticality of antimony and the advantages of securing a domestic supply of this strategic semimetal currently dominated by China and Russia.

Under a 2021 agreement, Perpetua will supply Ambri with the antimony it needs to produce liquid-metal batteries.

"Perpetua continues to show how a modern mining company can not only be an essential part of the clean energy value chain, but also be key to the solution to the world's climate challenges," said Sayer. DMN

Vanadium is used to add strength and durability to tool steels.
ADOBE STOCK

Vanadium strengths go beyond alloys

Flow batteries a major potential future use of alloying metal

By SHANE LASLEY
DATA MINE NORTH

VANADIUM, A METAL BEST KNOWN for its role in making extremely tough steel used in tools and auto parts, is emerging as a metal that could allay shortages of lithium, nickel, and other ingredients needed for the batteries powering electric vehicles. While vanadium flow batteries will not be powering EVs anytime soon, this technology could diversify energy storage by serving as an alternative to lithium-ion batteries for the large-scale storage of electricity from renewables.

"This emerging grid-scale storage technology has great commercial and energy security potential," said Allan Tuan, commercialization manager for energy, grid, and advanced fuel research at the U.S. Department of Energy's Pacific Northwest National Laboratory.

Taking advantage of vanadium's ability to exist in a solution in four different oxidation states and using this property to make a battery that needs just one element for both the positive and negative electrolyte solutions, vanadium redox flow batteries have shown the potential to be the superior choice for large-scale energy storage.

Vanadium redox batteries, or VRFBs, offer several advantages – ease of scalability, reliability, flexibility, quick response, and safety – over lithium-ion and other batteries for keeping energy grids energized and stable.

The amount of energy a VRFB can store is only limited by the size of the storage tanks built to hold the vanadium electrolytes, which are separated by a membrane that allows vanadium electrons to flow back and forth during charging and discharging.

"The emerging need for large-scale electricity storage makes vanadium redox flow batteries a major potential future use of vanadium," USGS wrote. "Because of their large-scale storage capacity, development of VRBs could prompt increases in the use of wind, solar, and other renewable, intermittent power sources."

ENERGY FUELS INC.

Energy Fuels' White Mesa Mill near Blanding, Utah produces advanced rare earth carbonates, vanadium, and uranium.

Above the touted superiorities, using flow batteries for large-scale stationary energy storage would relieve some of the stress off lithium-ion battery supply chains that are already being scaled up at a tremendous rate to keep pace with the manufacturing of hundreds of millions of EVs expected to be traveling global highways within two decades.

Much like the minerals and metals needed for lithium-ion batteries, the growth of the renewable energy sector could drive unprecedented new demand for vanadium.

China and Russia, however, accounted for roughly 84% of the vanadium produced during 2021. The balance was mined in Brazil and South Africa.

While a trifle of vanadium was produced from waste materials in North America last year, Canada and the United States each host rich deposits of this steel strengthening and emerging battery metal.

Superior vanadium steel

Vanadium is following the same career path as nickel – from an alloy metal used to make superior steels to an ingredient critical to the global transition to electric transportation charged with renewable energy.

The commercialization of vanadium flow batteries, however, lags way behind the lithium-ion batteries that are demanding massive new supplies of nickel.

The USGS estimates that 94% of the roughly 4,500 metric tons of vanadium consumed in the U.S. during 2021 was used in steel and other alloys.

Vanadium traces its alloying legacy back to the earliest days of the 20th century, when manufacturers in Europe began taking advantage of the lighter, more durable, and flexible vanadium steels to give their racecars an edge.

This inspired Henry Ford to use vanadium steel in the crankshafts, springs, wheel spindles, and other stressed parts in its famed Model T in 1908.

These characteristics were used to tout "Ford superiority" in car building at the time. More than a century later, the "Built Ford Tough" slogan for the American automaker's trucks is an echo of the strength vanadium imparted to the Model T.

The chrome-vanadium proudly stamped on tools found in nearly any hardware store is a more direct reference to the toughness vanadium imparts to steels used to make tools and a wide range of other products where strength is of utmost importance.

"The high-strength, low-alloy (HSLA) steels containing vanadium are widely used for the construction of auto parts, buildings, bridges, cranes, pipelines, rail cars, ships, and truck bodies, including armor plating for military vehicles," the USGS wrote.

While other metals could replace ferrovanadium steel alloys, it is typically not worth the costs and energy required to create steel that can compete with those imbued with vanadium's properties.

Steel, however, is not the only alloy enhanced by vanadium. When it comes to strength-to-weight ratio, titanium-vanadium alloys are among the best materials ever engineered. This is invaluable to an aerospace sector seeking to shave pounds of aircraft and space vehicles without sacrificing durability.

"Vanadium, when combined with titanium, produces a stronger and more stable alloy, and when combined with aluminum produces a material suitable for jet engines and high-speed airframes," USGS inked in the vanadium section of a 2018 report on critical minerals. "No acceptable substitutes exist for vanadium in aerospace titanium alloys."

Disruptive battery tech

While strong and stable alloys currently drive the market for vanadium, emerging vanadium redox flow battery technologies have the potential to be a market disruptor for this metal.

Global Industry Analysts Inc., a California-based market research firm, forecasts that the vanadium flow battery market will rocket to US$592 million by 2026, more than double the estimated US$238 million this year.

"The market is expected to be driven primarily by factors, such as their lower environmental impact in terms of battery disposal and higher energy capacity owing to the presence of larger tanks for electrolyte storage," GIA penned in its vanadium redox battery report. "These batteries contain no toxic or highly reactive substance and pose no fire hazard, making them more environment-friendly as compared to lead-acid and lithium-ion batteries."

The market analytical firm, however, says VRFBs suffer from two disadvantages that are holding the technology back – higher capital costs and lower energy density.

DOE's Pacific Northwest National Laboratory has been carrying out research aimed at overcoming these obstacles.

PNNL, which has partnered with two companies that are bringing this technology to market, offered a third and final semi-exclusive vanadium battery technology license earlier this year.

"We are eager to partner with additional industry partners to bring this technology to market and to support expanded use of

renewable energies on the grid," said Tuan.

With the growing need for grid-scale storage of intermittent solar- and wind-generated electricity, utilities are expected to be a major market for vanadium redox batteries.

GIA expects 830 gigawatt-hours of wind energy and 970 GWh of solar energy to be added to energy grids by 2025, which is likely to drive the adoption of vanadium redox batteries in the coming years.

CellCube has emerged as a frontrunner in manufacturing vanadium redox flow batteries for the grid-scale storage of renewable energy in the United States.

CELLCUBE

U.S. vanadium flow batteries

Getting ahead of the expected growing demand for vanadium redox flow batteries in North America, Austria-based Enerox GmbH, better known as CellCube, has established a U.S. subsidiary in Colorado and cut a deal to buy electrolyte for its VRFBs from Arkansas.

"With our proven and bankable technology, we are capable to accelerate the energy transition and help achieving challenging climate targets," said Alexander Schoenfeldt, CEO of CellCube Austria and USA. "Being a global leader in this space we are very enthusiastic about our new presence in North America, as it will allow us to build and use local supply chain and engage with our business and R&D partners in the U.S. more easily. As a result, we will offer the best-in-class product in North America in a very sustainable and innovative way."

While CellCube announced the opening of its Denver office in May, the Austrian battery manufacturer has been among the most active participants in scaling up VRFBs in North America in recent years.

This includes contracts to purchase ultra-high-purity electrolyte from U.S. Vanadium LLC's facility in Hot Springs, Arkansas.

"As part of our go-to-market in North America, we want to use electrolyte which has been regionally processed within North America ensuring long-term deliverability at a competitive price," said Schoenfeldt.

After an expansion completed in February, which was supported by CellCube, U.S. Vanadium's plant has the capacity to produce 4 million liters of ultra-high-purity electrolyte per year.

The electrolyte and other high-purity vanadium-based products produced at the Arkansas facility are recovered from a variety of post-industrial waste streams imported by U.S. Vanadium. This means the electrolyte it produces has a much smaller carbon footprint than if it were generated from primary vanadium mining operations, a climate advantage that will be passed on to the renewable energy projects that utilize the electrolyte in their storage systems.

"We are pleased to have secured access to U.S. Vanadium's ultra-high pure electrolyte long-term, which in combination with our own post-production handling in the U.S. marks the opening of a new era of cooperation in the industry," Schoenfeldt added.

CellCube says the demand for the long-duration energy storage solutions that vanadium batteries offer has reached an all-time high, especially following the more aggressive climate commitments made by most countries during the U.N. Climate Change Conference (COP26) in Glasgow, Scotland.

The Austrian company says the microgrid market in the U.S. is a significant contributor to exploding demand that is creating a vanadium supply situation.

CellCube's first U.S. installation is an eight-megawatt-hour VRFB microgrid system at an industrial manufacturing site near Chicago. At the time, CellCube entered into an agreement to purchase 580,000 liters of high-purity electrolyte per year from U.S. Vanadium.

Under a newly expanded agreement reached in March, CellCube can purchase up to 3 million liters of U.S. Vanadium electrolyte per year.

"This agreement reflects today's rapidly accelerating growth of the vanadium redox flow battery industry and of U.S. Vanadium's ability to supply VRFB manufacturers with Made-in-America ultra-high-purity electrolyte," said U.S. Vanadium CEO Mark Smith. "We look forward to supplying CellCube, and customers around the world, with the finest and highest purity VRFB electrolyte now available on the market."

In addition to securing a reasonably priced supply during what is expected to be a competitive market, CellCube says the purchase agreement ensures the quality and consistency of the electrolyte going into its vanadium batteries.

"This move is aimed at more standardization of electrolyte and its processing to achieve high quality performance for a 20-year-plus operation without any capacity loss," Schoenfeldt said.

Energy fuels from Utah

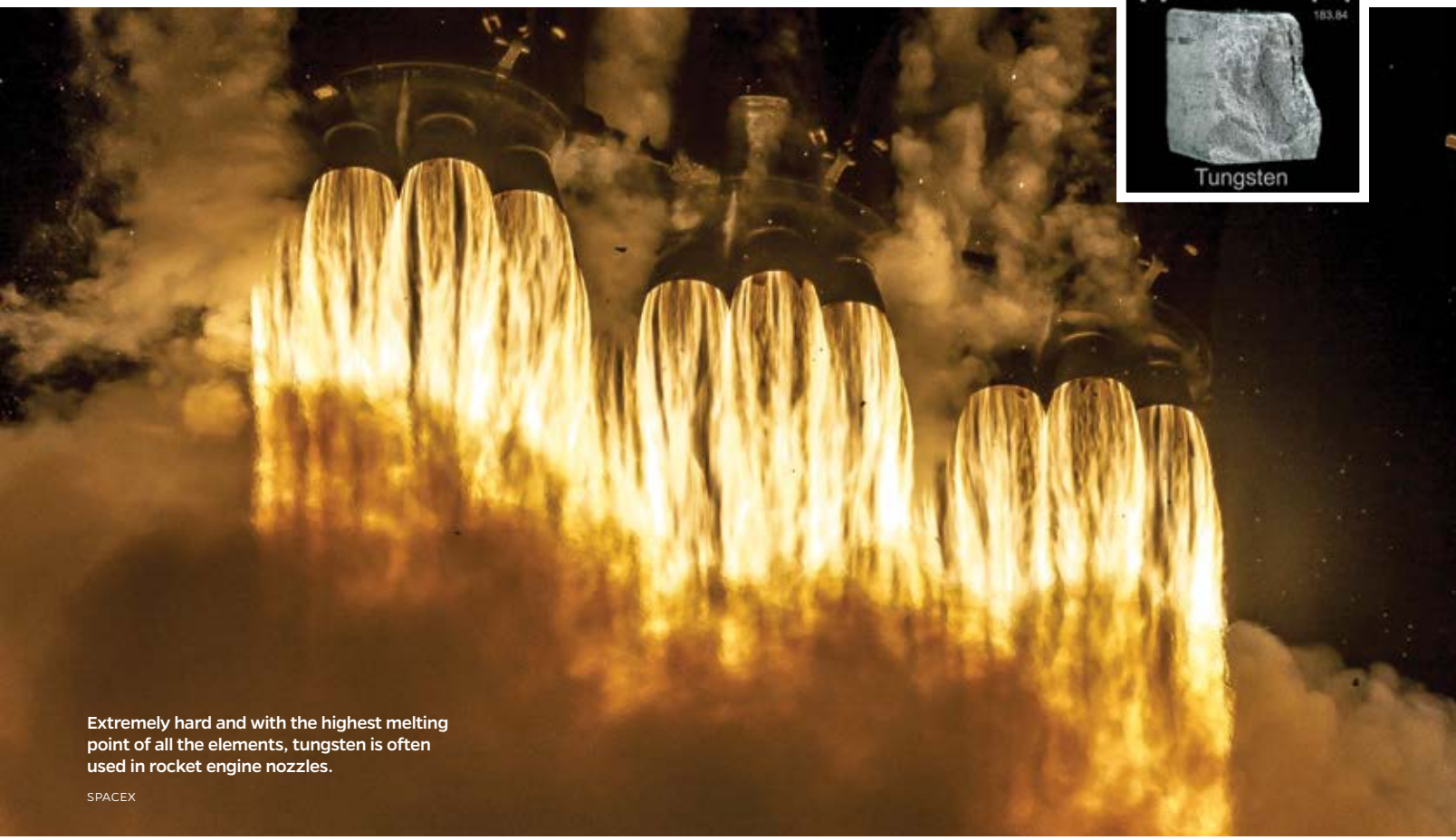
While there was no vanadium mined in the U.S. or Canada during 2021, one operation in Utah resumed production earlier this year, and both countries have the potential to produce much more of the alloying battery metal.

In April, Energy Fuels Inc. announced that it had shipped vanadium, rare earths, and uranium – a trifecta of mineral products critical to the production, storage, and use of low-carbon energy – from its White Mesa Mill in Utah.

"We believe we are moving faster than any other company in the U.S. on restoring low-cost, domestic critical material supply chains," said Energy Fuels President and CEO Mark Chalmers.

The vanadium pentoxide shipped from White Mesa was not destined for batteries. Instead, the critical metal was shipped to the Bear Metallurgical Company in Pennsylvania for conversion to ferrovanadium, which will be sold into the steel and specialty alloys industries.

"At Energy Fuels, we don't just talk about restoring critical domestic supply chains. We innovate, invest, and work hard to actually do it, all to the highest environmental, human health, and human rights standards in the world," said Energy Fuels President and CEO Mark Chalmers. DMN



Extremely hard and with the highest melting point of all the elements, tungsten is often used in rocket engine nozzles.

SPACEX

Strongest metal shows US supply weakness

Tungsten could become held ransom unless domestic mines open

By A.J. ROAN

DATA MINE NORTH

TUNGSTEN, OR WOLFRAM, is the 74th element on the periodic table of elements and, like many other metals that have found their way onto critical mineral lists in Canada, Europe, and the United States, this sturdy metal is vulnerable to supply disruption.

Tungsten has been known since prehistoric times, and as far back as 350 years ago, Chinese porcelain makers were using this element as a pigment to incorporate a unique peach color into their designs.

Its provenance as one of the toughest elements on Earth began in 1779 when an Irish mineralogist and chemist named Peter Woulfe discovered a new metal while examining ore from Sweden.

Ironically, the name wolfram does not originate from Woulfe but from one of its principal ores, wolframite, which was named some 30 years earlier.

Two years after Woulfe's findings, a Swedish-German pharmaceutical chemist named Carl Wilhelm Scheele discovered that a new acid, tungstic acid, could be made from scheelite – which at the time was called tungsten. From this, he deduced that a new metal could be obtained by reducing this acid.

Despite both scientists getting close, the discovery of tungsten is attributed to brothers José and Fausto Elhuyar, Spanish chemists who found an acid made from wolframite that was identical to tungstic acid. Thus, at the Royal Basque Society in the town of Bergara, Spain, the brothers succeeded in isolating tungsten by reduction of this acid with charcoal and are forever credited with the discovery of the heavy metal.

Strategic metal

The strategic value of tungsten came to notice in the early 20th century when British authorities acted to free the Carrock mine from German control. However, tungsten would play a more

significant role during World War II when political tensions in Europe were at their highest.

Portugal, as the main European source of the element, was put under pressure from both sides because of its deposits of wolframite ore at Panasqueira.

Due to tungsten's desirable properties, such as resistance to high temperatures, its hardness and density and its strengthening of alloys, this made it an important raw material for the arms race, both as a constituent of weapons and equipment but also in the production of tungsten carbide cutting tools for machining steel.

Nearly 60% of the tungsten consumed in the U.S. during 2020 was used to make cemented tungsten carbide, a compound of roughly equal parts tungsten and carbon.

Nearly twice as strong as steel, tungsten carbide is often found on the working end of drill bits, saw blades, wear plates, and other items that require this compound's toughness to meet some of the most demanding conditions in the mining, oil and gas, construction, and metal-working industries.

Tungsten carbide's hardness and density also make this metallic compound ideal for making armor-piercing ammunition for the military.

Of all metals in pure form, tungsten has the highest melting point (6,192 degrees Fahrenheit). Because it retains its strength at these high temperatures, elemental tungsten is used in many high-temperature applications.

Heating elements, lightbulb filaments, rocket engine nozzles, and TIG (tungsten inert gas) welding are among the many applications that take advantage of tungsten's ability to hold up to heat.

A beautiful hunk of wolframite (ferberite) with a scattering of siderite from the Panasquiera Mines in Portugal.

WIKIMEDIA COMMONS

US criticality

According to the United States Geological Survey Mineral Commodity Summaries 2022, world mine production and reserves for 2021 include:

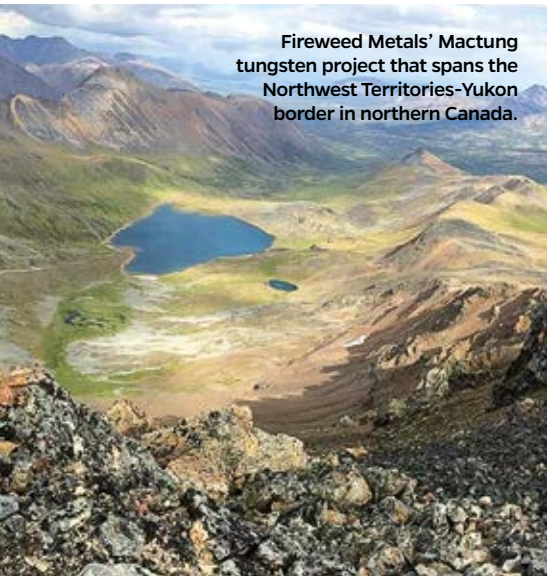
- China – 66,000 metric tons produced and 1.9 million metric tons of reserves.
- Vietnam – 4,500 metric tons produced and 100,000 metric tons of reserves.
- Russia – 2,400 metric tons produced and 400,000 metric tons of reserves.
- Bolivia – 1,400 metric tons produced with reserve amount not available.
- Rwanda – 950 metric tons produced and reserve amount not available.
- Austria – 900 metric tons produced and 10,000 metric tons of reserves.
- Spain – 900 metric tons produced and 52,000 metric tons of reserves.
- North Korea – 400 metric tons produced and 29,000 metric tons of reserves.
- Portugal – 620 metric tons produced and 5,100 metric tons of reserves.

And finally,

- United States – zero metric tons produced and reserve amount not available.

"World tungsten supply was dominated by production in China and exports from China," the USGS wrote in its report.

Last year, China's government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate product,



Fireweed Metals' Mactung tungsten project that spans the Northwest Territories-Yukon border in northern Canada.

GOVERNMENT OF NORTHWEST TERRITORIES

and placing constraints on mining and processing.

Reduced production during or after purported environmental and safety inspections at Chinese mining operations contributed to periods when supplies of tungsten concentrates were down from China.

While production of tungsten concentrate outside of China was expected to increase in 2021, it remained less than 20% of the world's production.

As a stopgap, the U.S. government has been supplementing its own supply out of its stockpiles, and according to USGS data, the available amount in the stockpile was down nearly 1,000 metric tons from the previous year leaving only 6,850 metric tons.

However, there are ample possible mine sites that could stymie the potential risks of having China lock its supply down completely, albeit if they ever get through permitting or if they become available from being sealed away in conservation areas.

North American Tungsten

Tungsten resources are plentiful for this heavy metal in Canada and the U.S., especially the Rocky Mountain states and provinces, as well as Alaska, Yukon, and Northwest Territories.

Mines along the Yukon-Northwest Territories border are past tungsten producers and are among the most promising projects for restoring a North American supply of this durable critical metal.

According to a 2014 technical report prepared for North American Tungsten, a company that fell into financial difficulties in its attempts to resume tungsten mining in this area, the Cantung project hosts 3.84 million metric tons of indicated resources averaging 0.97% tungsten trioxide, and 1.37 million metric tons of inferred resources grading 0.8% tungsten trioxide.

Mactung, which is about 100 miles northwest of Cantung, hosts 33 million metric tons indicated resource averaging 0.88% tungsten trioxide, making it one of the largest known undeveloped, high-grade tungsten-skarn deposits in the world.

Despite Mactung's world-class size and grade, along with being advanced well into permitting, North American Tungsten had to file for creditor protection before it could develop the mine that would have produced roughly 750,000 metric tons of tungsten per year, which would have been added to the 383,000 metric tons per year being produced at Cantung up until around 2015.

Following North American Tungsten's bankruptcy, a court-appointed monitor oversees site operations, which is funded by the federal government.

Canadian mineral explorer Fireweed Metals Inc., however, recently agreed to buy the Mactung tungsten project from the NWT government for C$15 million.

As it lies adjacent to the company's flagship Macmillan Pass zinc-lead-silver project in the Yukon, the company has decided to add this strategic property to its quickly growing portfolio of critical minerals and metals.

"We now have not only one of the largest undeveloped zinc resources in the world at our Macmillan Pass Project, but also one of the world's largest and highest-grade undeveloped tungsten projects at the advanced stage Mactung Project," said Fireweed Metals CEO Brandon Macdonald. "With both zinc and tungsten being designated as critical minerals by Canada, the US, and the EU, Fireweed is positioned to leverage the transition to a sustainable green economy."

Cantung, however, remains under care and maintenance directed by the court-appointed monitor.

Viable tungsten and copper reserves remain at the Cantung mine, and the territorial government is looking for a company to resume operations at the mine before the site is remediated and eventually closed.

At least six tungsten exploration projects are located just across the border in Canada's Yukon.

Locked away Bear Mountain

While there is not any tungsten produced in the U.S. today, this sturdy, industrial metal was historically mined in several Alaska locales to meet America's needs during both World Wars.

The gold-rich hills around Fairbanks, in the heart of Alaska's interior, are one of the past-producing tungsten regions.

However, the largest deposit of tungsten in Alaska may lie in the Bear Mountain occurrence along the southern slopes of the Brooks Range.

During visits to Bear Mountain in the 1980s, U.S. Bureau of Mines geologists James Barker and R.C. Swainbank identified a 100-acre area of surface mineralization indicative of a large porphyritic molybdenum-tungsten deposit.

Analysis of 20 soil and 36 rock samples collected during 1985 returned abundant tungsten and molybdenum along with lesser amounts of niobium.

Soil samples collected at the time returned tungsten values exceeding 500 parts per million wolframite, with the best samples containing 5,000 ppm of this tungsten mineral.

"I believe Bear Mountain to be likely the most important tungsten deposit in the U.S.," Barker, who spent much of his career doing critical mineral assessments for the former U.S. Bureau of Mines, told Data Mine North.

The potential of this intriguing tungsten-molybdenum discovery, however, may never be realized due to its location.

In addition to being in a remote corner of northeast Alaska, this potentially world-class tungsten-molybdenum deposit is situated within the Arctic National Wildlife Refuge, or ANWR, a 19.3-million-acre region set aside for wilderness and wildlife conservation.

"It's a shame that mineral evaluations aren't done before we place an area off-limits," Barker reflected.

While Bear Mountain tungsten, molybdenum, and niobium may be stored in a restricted reserve, past-producing mines in Alaska and Northwest Territories have answered North America's urgent call for tungsten in the past and have the potential to answer a similar call should a pressing need for the durable industrial metal rise again in the future. DMN

The widespread use of niobium in pipe steels started with the 1970s construction of the Trans-Alaska Pipeline System.

LUCA GALUZZI/CC BY 2.0

Niobium gets promotion into high-tech

Superconductors, super magnets, and superalloys, this metal is super

By A.J. ROAN
DATA MINE NORTH

THE STORIES BEHIND, the discovery of many elements in the periodic table make for a fascinating read, but perhaps top among them should be the 41st element, a shiny, white metal known as niobium – for its story spans over centuries, with twists and turns befitting even the best piece of fiction.

Due to the astute observations of Charles Hatchett, a self-educated scientist and analytical chemist, niobium was discovered. Coming upon an ore sample at the British Museum, a specimen described as a "very heavy black stone with golden streaks," Hatchett began his research.

By obtaining samples from the museum and subjecting them to exhaustive chemical analysis, Hatchett determined that columbite contained a new element. Regardless of his inability to isolate the element, he shared his findings with the Royal Society about his discovery, which he named columbium, in 1801.

Two years later, Swedish chemist Anders Gustaf Ekenberg discovered the element tantalum in minerals obtained in his homeland. While chemically similar, columbium, or niobium, was often found along with its twin, tantalum, making it difficult to isolate or identify.

It was then that another scientist, a chemist by the name of William Hyde Wollaston, became suspicious that columbium and tantalum may, in fact, be the same element that he started investigating the ores from Ekenberg. Upon comparing the physical and chemical properties of both materials, his conclusion in 1809 was both elements were the same, removing the possibility of two separate elements for nearly half a century.

As Hatchett, who had come from an affluent family and had taken over his family's coach-building business following his father's passing – and had effectively given up on science completely by this time – there was no one to defend his discovery, and Wollaston's opinion prevailed.

This would remain the case until 1844, when German mineralo-

gist and analytical chemist Heinrich Rose, working with samples of columbite and tantalite, produced two new acids, which were very similar yet different.

Naming the new acid obtained from columbite as niobic acid and its metallic component as niobium – after Niobe, one of the children of Tantalus from Greek mythology – Rose had effectively rediscovered columbium and renamed it niobium.

Today, both names are still used, with the usage depending on region and country (America seemingly preferring columbium), yet the avid study of the almost missed element persisted and was later added as the 41st element in 1949.

Blue-collar niobium

Though it is tough to distinguish the nearly identical properties of niobium and tantalum in nature, in industry, one of these twin metals typically dons a hardhat and work boots in the construction and energy industries, while the other is found employed in the high-tech sector.

"The leading use of niobium is in the production of high-strength steel alloys used in pipelines, transportation infrastructure, and structural applications," the United States Geological Survey wrote in 2018 regarding the paired metals.

As for its place as a critical mineral, much like its twin tantalum, the U.S. is 100% import-reliant, and one cannot find a good substitute for either without sacrificing performance or increasing costs.

A tough metal that is resistant to corrosion and boasts an exceptionally high melting point, niobium tends to be the blue-collar metal compared to its "bougie" brother.

"Niobium microalloyed high strength steel plates are used in a variety of applications, such as large diameter line pipe for the transmission of gas and oil, shipbuilding, offshore platforms, bridges, and energy generation structures such as wind turbines," according to Oakley Steel.

The Asian steel supplier says that less than 0.1% niobium is all that is needed to boost the strength, toughness, and weldability of steel.

Niobium's extreme resistance to heat and corrosion also makes this strong metal an important ingredient for iron-, nickel-, and cobalt-based superalloys that need to stand up to high temperatures.

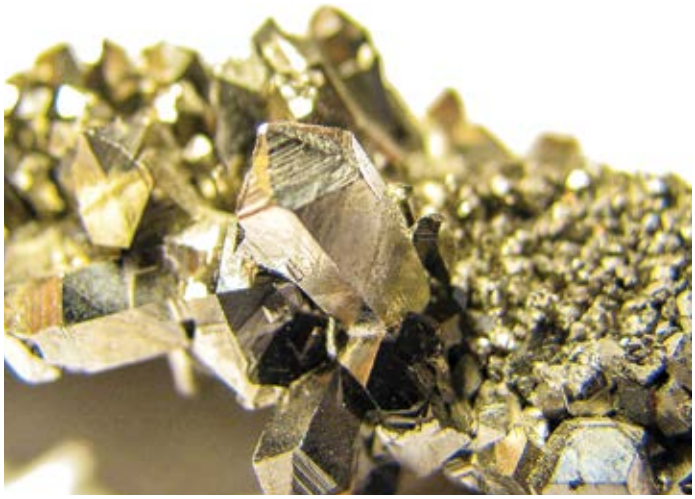
Roughly 20% of the niobium consumed in 2021 was used to make high-temperature superalloys for parts that go into jet engines, rockets, gas turbines, and turbochargers. The remaining 80% went purely into steel production.

Adding to its résumé of "super" properties, niobium is among the most powerful superconducting metals, and perhaps a job promotion from its more rugged responsibilities, as superconducting magnets made from niobium-germanium, niobium-tin, and niobium-titanium alloys are used in a range of important devices, from imaging equipment to particle accelerators.

Furthermore, recent exploration into the world of two-dimensional materials has shown the possibility of niobium-bromine contributing to next-generation semiconductors and superconductors, a fitting position for this super metal.

So, while niobium has found its career in

Right: Niobium, or columbium, is a chemical element with the symbol Nb and atomic number 41. Light gray, crystalline, and ductile, niobium is a transition metal meaning it is unstable and can exhibit transformative properties between other elements.



WIKIMEDIA COMMONS

>> Significant U.S. niobium mine production has not been reported since 1959, so to have such a promising mine in development during a time when these metals are fundamental to a renewable energy future could not be better timed.

heavy-duty manufacture, it does not seem too implausible for it to make its way into similar fields as its twin, what with them being nearly identical in practically every aspect.

North American supply

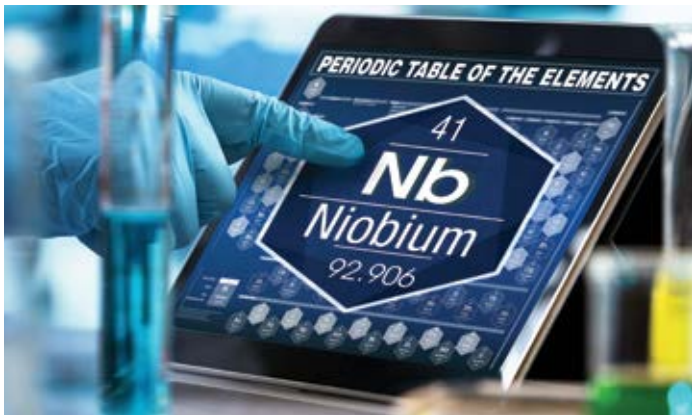
While America is still 100% reliant on niobium, efforts to create a homegrown supply chain are underway, with NioCorp Developments Ltd. planning to produce the metal – along with scandium, titanium, and rare earths – at its Elk Creek mine project in Nebraska.

An updated feasibility study reports that Elk Creek hosts 632,000 metric tons of total rare earth oxides, 970,300 metric tons of niobium oxide, along with 11,337 metric tons of scandium, and 4.2 million metric tons of titanium oxides in the indicated resource category.

Including the 15 individual rare earth elements, this unique deposit hosts 18 of the 50 minerals deemed critical to America's economic wellbeing and national security.

Significant U.S. niobium mine production has not been reported since 1959, so to have such a promising mine in development during a time when these metals are fundamental to a renewable energy future could not be better timed.

"Given recent geopolitical events and the world's ongoing global energy transition, we feel a strong imperative to produce more of the critical minerals that America and the Western world need to meet these challenges," said NioCorp Developments Executive Chairman and CEO Mark Smith. "The updated feasibility study shows that the Elk Creek deposit contains an abundance of critical minerals, including rare earths, and we are working very hard to ensure America can benefit from the full range of the critical minerals our deposit could economically deliver."



ADOBE STOCK

The feasibility study outlines an underground mine at Elk Creek that would produce an estimated 170,409 metric tons of niobium, 431,793 metric tons of titanium, and 3,677 metric tons of scandium over 38 years of mining.

The company is currently working toward the recovery of rare earths alongside these other critical metals in its Nebraska deposit.

If successful, this process could not only add REEs to the payable metals recovered at the operation but also streamline and optimize the recovery of its primary deposits – niobium, titanium, and scandium.

In March, the company reported that bench-scale testing of this process was successful, and the testing is being scaled up to a demonstration-scale plant. If this testing confirms that this optimized process will be technically and economically feasible for Elk Creek, NioCorp will incorporate the rare earth capturing optimized recovery process into an updated technical report.

"With the addition of the magnetic rare earths, the Elk Creek project will stand out from virtually every other greenfield project in the U.S. in terms of its potential ability to produce multiple critical minerals that are essential to electrified transportation, renewable energy production, green mega-infrastructure projects, and many other applications that are in increasing demand around the world," said Smith. DMN

A silvery metal that will turn to liquid in the palm of your hand, gallium has emerged as critical element for scrubbing carbon dioxide from the atmosphere.

ADOBE STOCK

Gallium may be more critical than realized

CO2 scrubbing liquid-metal catalyst is latest amazing property

By SHANE LASLEY

DATA MINE NORTH

FROM MAKING SMARTPHONES smarter to transforming troublesome carbon dioxide into useful oxygen and high-value carbon products for batteries and other advanced products, gallium is an amazing tech metal lending its incredible qualities to high-performance computers, telecommunications, national security, and the environment.

A soft silvery metal that will turn to liquid in the palm of your hand due to its 85.6-degree-Fahrenheit melting point, gallium is the primary ingredient in two semiconductors, gallium arsenide and gallium nitride, used in next-generation smartphones, telecommunication networks, light-emitting diodes (LEDs), thin-film solar cells, and medical devices.

"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," the U.S. Geological Survey penned in a report on

FOOBAR PHOTOGRAPHY/CREATIVE COMMONS

Above: A superconductor with an 86-degree Fahrenheit melting point, gallium is increasingly being used in 5G networks, solar energy, smartphones, 5G telecommunication networks, and potentially liquid-metal catalysts.
Right: Appia Rare Earths' Alces Lake rare earths project in northern Saskatchewan may host the highest-grade gallium deposit in North America.

minerals and metals considered critical to the United States.

Gallium nitride is used principally in the manufacture of LEDs and laser diodes, power electronics, and radio-frequency electronics. Considered superior to traditional semiconductors, 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 tech metal 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," according to the USGS.

Growing demand is pushing the price of this semiconductor metal higher.

Over the past two years, the price for a kilogram of gallium has nearly tripled, from US$284 per kilogram of 99.995% gallium metal in mid-2020 to US$827/kg in mid-2022.

Most of the gallium used by America's high-tech sectors originates in China, which accounted for 98% of 420,000 kilograms of this tech metal produced worldwide in 2021. Most of the rest originated in Russia, the world's second-largest gallium producer last year.

While America's technology and renewable energy sectors do not need an enormous amount of gallium, USGS estimates that 16,000 kilograms were used in the U.S. last year; it is completely reliant on imports for this critical tech metal.

Liquid-metal CO2 scrubber

If making smartphones smarter and telecommunication systems faster was not enough to elevate gallium's criticality, two new discoveries show this liquid metal is great at scrubbing carbon dioxide from the atmosphere.

An international team of scientists led by Professor Kourosh Kalantar-Zadeh at the University of New South Wales School of Chemical Engineering in Australia has developed a reactor that uses gallium and nano-sized silver rods to break down CO2 into its constituent elements.

"Our liquid metal technology offers an unprecedent[ed] process for capturing and converting CO2 at an exceptionally competitive cost," said Kalantar-Zadeh. "We are very hopeful that this technology will emerge as the cornerstone of processes that will be internationally employed for mitigating the impact of greenhouse emissions."

The reactor generates tribo-electrochemical reactions, the process of using an electrical current to transfer electrons from a liquid onto a sold surface, to create oxygen gas and sheets of solid carbon that accumulate on the gallium.

In a paper detailing this technology, the researchers estimate that it will cost about $100 per metric ton to convert a metric ton of CO2 into oxygen and carbon.

Toward this objective, a startup company called LM Plus was created with the support of UNSW's Knowledge Exchange and seed

APPIA RARE EARTHS & URANIUM CORP.

investment from Uniseed.

LM Plus director and Uniseed investment manager Paul Butler said that in addition to the obvious value of scrubbing CO2 from industrial emissions prior to release into the atmosphere, carbon sheets produced by the technology can be used to make electrodes in batteries or carbon fiber materials for high-performance products like aircraft, racing cars, and luxury vehicles.

"What we are working towards now is to raise funds to build a larger size proof-of-concept for this system to work within a 40-foot container – the size of a truck trailer – that could ultimately help industrial sites immediately capture any CO2 emissions and convert them," Butler said.

Another Australian research team found that adding just a pinch of platinum to gallium created a liquid-metal catalyst that is better at scrubbing carbon emissions than solid-state platinum.

"From 2011, scientists were able to miniaturize catalyst systems down to the atomic level of the active metals," said lead author Arifur Rahim of UNSW. "To keep the single atoms separated from each other, the conventional systems require solid matrices to stabilize them. I thought, why not use a liquid matrix instead and see what happens."

The team found that platinum becomes soluble in liquid gallium.

For this mechanism, processing at an elevated temperature is only required at the initial stage, when platinum is dissolved in gallium to create the catalysis system. Despite this initial firing, roughly five times less heat is required for roughly an hour or so to produce the liquified platinum that remains a liquid at room temperatures.

Even more remarkably, at a ratio of less than 0.0001 platinum to gallium, this new liquid-metal alloy is 1,000 times more efficient than a solid-state catalyst with around 10% platinum.

The liquidity of the gallium-platinum alloy offers yet one more advantage – it is self-cleaning.

Like a water feature with a built-in fountain, the liquid mechanism constantly refreshes itself, self-regulating its effectiveness over time and avoiding the catalytic equivalent of pond scum building up on the surface.

As it turns out, platinum lends its catalytic abilities to gallium,

which is the driving force behind the reaction.

"The platinum is actually a little bit below the surface and it's activating the gallium atoms around it," said Andrew Christofferson, an Exciton Science associate investigator that worked on the project. "So, the magic is happening on the gallium under the influence of the platinum. But without the platinum there, it doesn't happen. This is completely different from any other catalysis anyone has shown, that I'm aware of."

These magical gallium properties could make the liquid metal a critical element in lowering atmospheric CO2.

North American gallium sources

The gallium needed for traditional high-tech and potential new green applications is typically recovered as a byproduct of mining more common metals – primarily aluminum and zinc.

While there are gallium-enriched base metal deposits in both the U.S. and Canada, two North American rare earths deposits – Round Top in Texas and Alces Lake in Saskatchewan – host richer stores of this critical metal.

Being advanced under a joint venture between USA Rare Earth LLC (80%) and Texas Mineral Resources Corp. (20%), the Round Top rare earths project in Texas is rich in a suite of critical minerals, including gallium.

According to a 2020 assessment by USGS, the Round Top deposit hosts a staggering 36.5 million kg of gallium, or roughly equivalent to 850 years of global needs based on 2021 production.

This enormous lode of gallium, however, is in low concentrations in a very large deposit.

The technology being developed to recover the rare earths mined from Round Top has also been designed to extract and purify the lithium, hafnium, zirconium, gallium, and beryllium also found in the critical Texas deposit.

"This new plant will process leach solutions from the Round Top ore using continuous ion exchange and continuous ion chromatography (CIX-CIC) to separate and purify up to a total of 26 different recoverable elements," according to USA Rare Earth.

While not as large or advanced as Round Top, Appia Rare Earths & Uranium Corp.'s Alces Lake rare earths project in northern Saskatchewan may host the highest-grade gallium deposit in North America.

An electron microprobe study conducted by the Saskatchewan Research Council first demonstrated that the rare earths-enriched monazite mineral from two separate zones and trends at Alces Lake was also enriched with gallium.

Drilling carried out over the past two years has further confirmed the high-grade nature of the rare earths and gallium in these zones. Highlights from this drilling include:

- 9.38 meters averaging 17.53% total rare earth oxides and 0.05% gallium trioxide.
- 4.3 meters averaging 3.62% TREO and 0.01% gallium trioxide.
- 3.33 meters averaging 7.98% TREO and 0.02% gallium trioxide.

The gallium grades are economically significant.

By way of example, it is estimated that the ore at Apex Mine in Utah, which was the only primary mined source of gallium and germanium in the U.S. before it was closed in 2011, averaged about 0.032% gallium.

"The presence of gallium in the high-grade REO system on the Alces Lake property helps distinguish the property as a potential world-class asset for high-valued critical elements required for sustainable production of advanced technological applications," said Appia Rare Earths President Frederick Kozak.

Considering the findings of the two studies out of Australia, these advanced technological applications could soon extend to lowering the amount of greenhouse gases in the atmosphere. DMN

Australian scientists have dissolved platinum in gallium to create a powerful, self-cleaning, liquid-metal catalyst.

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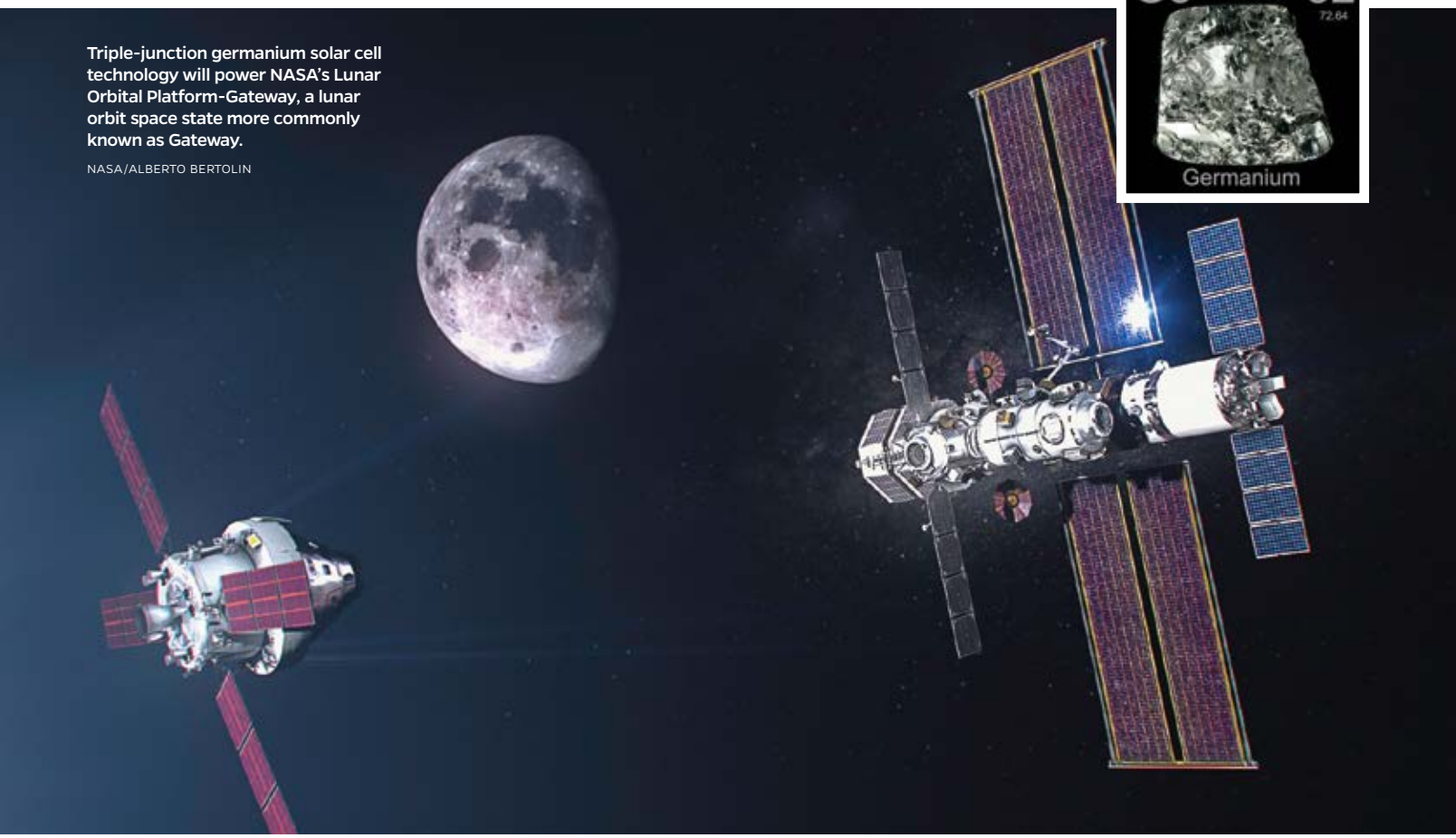


Triple-junction germanium solar cell technology will power NASA's Lunar Orbital Platform-Gateway, a lunar orbit space state more commonly known as Gateway.

NASA/ALBERTO BERTOLIN

Out of this world germanium properties

Tech metalloid boasts superior semiconductor, optical qualities

By SHANE LASLEY

DATA MINE NORTH

FROM NASA'S GATEWAY space station that will serve as a critical outpost circling the Moon to more down-to-Earth applications such as quantum computers that are millions of times faster than their classical counterparts and fiber optic cables that send data at the speed of light, germanium is among the techiest of the tech metals.

"The extensive use of germanium for military and commercial applications has made it a critical material in the United States and the rest of the world," the U.S. Geological Survey penned in a report on critical minerals.

Germanium traces its technological roots back to the 1950s, when scientists developed the transistor to replace vacuum tubes in the enormous mainframes of the day – a discovery that led to modern smartphones that are hundreds of thousands of times more powerful than the Apollo-era computers that guided Man's first flights to the Moon.

While germanium is the original and more powerful transistor semiconductor, it was supplanted by silicon, a more abundant and less expensive material that has become the namesake for the global capital of computer technology and the Digital Age.

Despite Germanium Valley never becoming a reality, the superior semiconducting and optical properties of this critical metalloid are empowering space exploration and high-speed communication networks here on Earth.

Out-of-this-world superconductor

As an intrinsic semiconductor, germanium is a powerful ingredient in triple-layered solar panels that are much more efficient at converting light into electricity than typical photovoltaic cells.

"Germanium substrates are used to form the base layer in

A truckload of zinc concentrates carrying byproduct germanium leaving Teck Resources' Red Dog Mine in Alaska.

ALASKA INDUSTRIAL DEVELOPMENT AND EXPORT AUTHORITY

multijunction solar cells, which are the highest efficiency solar cells currently available," according to the USGS.

These highly efficient but more expensive germanium-infused solar cells are the preferred photovoltaic power source for space missions.

"Whereas silicon is optimised to convert one specific part of the light spectrum into electricity, germanium allows for triple-junction cells. Each junction converts a different portion of the light spectrum into electricity, so overall conversion efficiency is a lot higher," explains Bendix De Meulemeester, business development director at Umicore Electro-Optic Materials, which provides germanium solar panels for past, current, and future space applications.

This germanium solar cell technology will power the Lunar Orbital Platform-Gateway, more commonly known as Gateway, which will soon serve as an outpost for long-term missions to Mars and beyond.

In the meantime, germanium solar cells are powering the Curiosity rover exploring Mars in preparation for human arrival.

"The solar cells are stacked in three layers on the rover's solar arrays and, because they absorb more sunlight, can supply more power to the rover's re-chargeable lithium batteries," NASA Jet Propulsion Laboratory explains.

Superior optical qualities

Despite its superlative-earning semiconductor notoriety, germanium's superior optical qualities – transparent to the infrared electromagnetic spectrum, can be formed into glass, exceptionally high refractive index, and low chromatic dispersion – are what drive the highest demand for this metalloid.

"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.

M2 Optics CEO Kevin Miller says chromatic dispersion, or the flattening of the initially sharply defined binary pulses of information, is an equally serious consideration when it comes to sending data over long distances via fiber optics.

"This degradation makes the signals (ones and zeros) more difficult to distinguish from each other at the far end of the fiber," he explains.

The International Energy Agency estimates that 5 billion people will be using the internet by 2025, a roughly 40% increase over the 3.6 million 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 cable and the germanium that goes in it.

As a result, the global fiber optic components market is expected to expand at a compound annual growth rate (CAGR) of 8.1%, reaching $36.3 billion by 2027.

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.

"Infrared optical devices improve a soldier's ability to operate weapon systems in harsh conditions effectively, and they are increasingly used in remotely operated unmanned weapons and aircraft," the USGS inked in its germanium report. "Infrared optical devices are also used for border patrol and by emergency response teams for conducting search-and-rescue operations."

While military and law enforcement are the major buyers of night-vision technology, USGS said commercial applications for thermal imaging devices that use germanium lenses have increased during the past few years.

Blockchain traces byproduct

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 byproduct from concentrates from mining zinc and other base metals.

"As a byproduct metal, the supply of germanium is heavily reliant on zinc production," the USGS penned in its report.

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 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 2022 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 computer transistors, solar cells, light-emitting diodes (LEDs), and night vision goggles, to name a few.

With the refinery processing concentrates from other mines, it is hard to track exactly how much of this germanium comes from Red Dog concentrates.

This situation has created a conundrum for agencies tracking critical minerals.

"Because zinc concentrates are shipped globally and blended at smelters ... the recoverable germanium in zinc reserves cannot be determined," USGS penned in its mineral commodities report.

With the use of blockchain technology, it will soon be possible to track Red Dog germanium from mine to customer.

Working with DTL Labs, a leading provider of blockchain-enabled technology, Teck is piloting a project that traces germanium from Red Dog through the Trail refinery and to a fiber optic cable manufacturer.

Over the past decade, businesses have identified many uses for blockchain technology, from the settlement of financial records to smart contracts and reliable, transparent traceability of supply chains.

DLT Lab's DL Asset Track technology will embed data into a digital passport that includes information on environmental, social and governance (ESG) along the entire germanium supply chain.

"DLT is proud that its DL Asset Track product is being adopted by Teck in setting the standard for an innovative product passport," said DLT Labs CEO Loudon Owen. "This product passport collects, stores, and provides reliable, tamper-proof, and real-time data at every stage in the resource supply chain from end-to-end, including comprehensive information about the provenance of the resources. Certainty of mine of origin, provenance and single source of truth are essential building blocks for an effective ESG program."

Teck believes that traceability and assurance of both origin and handling along the supply chain can play a role in supporting responsible production more broadly for essential metals and minerals.

"Teck is proud to be advancing the first use of blockchain technology to trace the critical mineral germanium from the mine all the way to the customer," said Teck Resources Senior Vice President of Sustainability and External Affairs Marcia Smith. "Ensuring the environmental and social responsibility throughout the metals production chain provides our customers and downstream consumers with the confidence that their products are sourced responsibly." DMN

ADOBE STOCK

Teck Resources is using blockchain technology to trace germanium from the Red Dog Mine to a fiber optic cable manufacturer.

The International Energy Agency estimates that roughly 11,020 lb of zinc is required for every megawatt of low-carbon electricity generated by wind.

ADOBE STOCK

Zinc galvanizes US critical minerals list

Blue-collar metal vital to weatherizing green energy future

By SHANE LASLEY

DATA MINE NORTH

CRITICAL MINERALS ARE TYPICALLY thought of as obscure rare earth elements cloaked in geopolitical intrigue, or exciting metals and metalloids that have risen to stardom due to the special properties they bring to cutting-edge technologies such as quantum computing, smartphones, renewable energy, and electric vehicles.

Zinc – a blue-collar metal better known for galvanizing guardrails, light poles, and buckets – is usually considered more essential than critical.

This hardworking base metal, however, landed on the United States Geological Survey's 2022 list of minerals and metals critical to America's security and economic wellbeing – an honor not even bestowed to copper, a metal essential to wiring the envisioned green energy future.

While not as glamorous as making smartphones smarter, wind turbines more powerful, or allowing electric cars to travel further and charge faster, zinc's corrosion-proofing abilities are in high demand as the Biden administration invests well over $1 trillion into upgrading and revamping America's infrastructure for the transition to EVs charged with low-carbon energy.

Above and beyond adding that dull gray weather-proofing layer seen on light poles, guardrails, and 5G telecommunication towers on your commute to work, zinc serves the same role in protecting the renewable energy infrastructure feeding low-carbon electricity into power grids.

According to the International Energy Agency, roughly 11,020 pounds of zinc is required for every megawatt of wind power-generating capacity. A whopping 529,000 lb is needed to galvanize a 100MW solar park, which could power 110,000 homes at full capacity but in practical terms would be sufficient for 20,000 homes or less depending on the amount of available sunshine.

In addition to corrosion-proofing the growing renewable energy infrastructure, zinc is also finding its way into batteries that store

the intermittent electricity produced by solar and wind.

Zinc-air batteries are one particularly exciting technology that leverages an underutilized property of the blue-collar metal to safely and efficiently store large quantities of energy for delivery to electrical grids after the sun sets and the breezes are gentle.

Analysts predict that renewable energy and battery storage sectors alone will require 364,000 metric tons (802.5 million lb) per year in 2030, which is more than three times the 109,300 metric tons (241 million lb) needed for these applications during 2020.

The massive new supplies of zinc needed for the American infrastructure and renewable energy buildout, coupled with the fact that current global zinc mining operations are already having a hard time keeping up with baseload demand, weighed on the USGS decision to add this galvanizing metal to the list of minerals and metals critical to the U.S.

This new status instantly elevated Teck Resources Ltd.'s Red Dog Mine in Northwest Alaska to being the largest critical mineral-producing operation in America, both in terms of quantity and value of the materials produced.

Rising demand, prices

Even before the $1 trillion Infrastructure Investment and Jobs Act was signed into the Bipartisan Infrastructure Law by President Biden, global demand for zinc was heating up.

Galvanized steel production in North America for 2021 increased by an estimated 19.6% over 2020, and European production was up over 15.5%. While much of this was the result of recovery from the COVID-19 pandemic, it speaks to the sharp rebound in demand for zinc.

In fact, 2021 galvanized steel production in the U.S. is estimated to have hit its highest level since 2012.

■ *Find out more about germanium at* ***Out of this world germanium properties*** *on page 93.*

Zinc metal markets in Europe and North America remained tight, pushing zinc prices higher. The average price for the galvanizing metal was around $1.40/lb last year, up roughly 30% from 2020 and moving higher as the year wore on.

The price for a pound of zinc rocketed from an average of $1.53 during the fourth quarter of 2021 to above $2.00/lb in April before settling back down to around $$1.70/lb by midyear.

Infrastructure and COVID-relief spending in the U.S. and around the globe, coupled with pent-up demand for consumer goods, automobiles, and housing is forecast to keep zinc demand and prices strong.

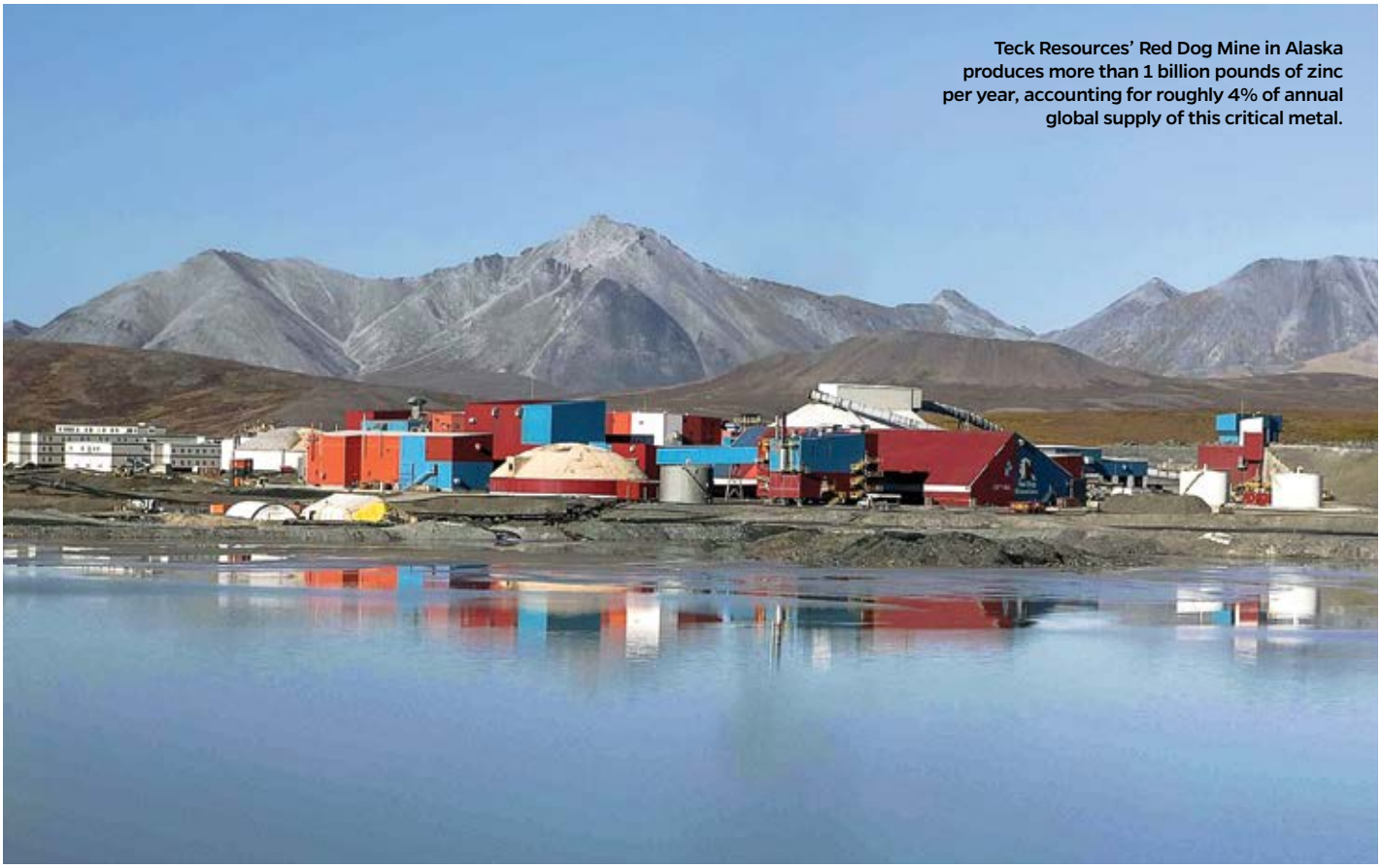
With zinc prices moving into record territory and Red Dog expected to produce more than 1.2 billion lb of the galvanizing metal this year, which singlehandedly accounts for approximately 4% of global supply, 2022 should be a banner year for this critical mineral mine in Northwest Alaska.

"In 2022, we expect a significant increase in zinc production at Red Dog and a decline in total cash unit cost before byproduct credits despite ongoing cost inflation pressures," Teck Resources CEO Don Lindsay informed investors and analysts in February.

In addition to zinc, Red Dog produces germanium and silver – metals critical to smartphones, supercomputers, and high-efficiency photovoltaic solar cells.

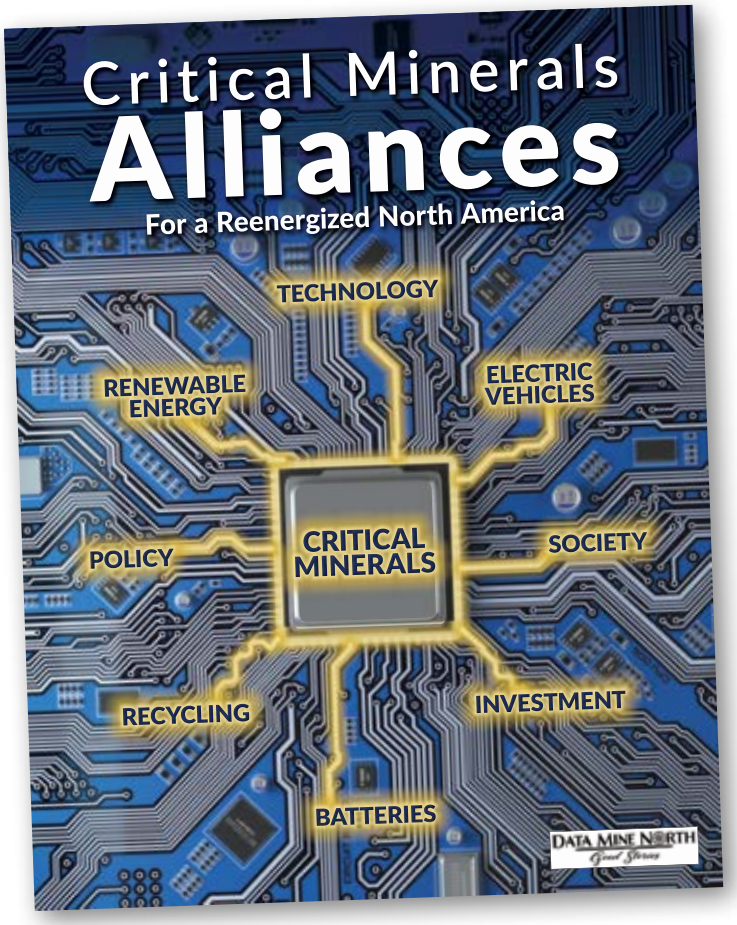
Zinc batteries

While galvanizing the global transportation, communication,



Teck Resources' Red Dog Mine in Alaska produces more than 1 billion pounds of zinc per year, accounting for roughly 4% of annual global supply of this critical metal.

NANA REGIONAL CORPORATION



and energy infrastructure is the primary driver of strong zinc demand and prices, the blue-collar metal is a rising star in the realm of grid-scale renewable energy storage.

Whether it be storing solar, wind energy, or even fossil fuel energy, the ability to store excess electricity and then deliver it when customers demand it most is an essential element to lowering the carbon intensity of global power grids.

So far, lithium-ion batteries have dominated this arena due to being a known and well-understood technology. Lithium batteries, however, are better suited for portable electronics and EVs, technologies that are putting enormous demands on the minerals and metals needed for these common rechargeable cells.

Zinc-air batteries offer a viable, safer, and lower-cost option for large-scale energy storage.

Electricity flowing into a zinc-air battery splits the oxygen off zinc oxide and is stored in the resultant charged zinc particles. This stored electricity is released back to the grid by reuniting the charged zinc particles with oxygen, regenerating the zinc oxide for reuse.

These batteries can hold a charge much longer than their lithium-ion counterparts, do not catch fire, and are up to five times less expensive to operate than their lithium-ion counterparts with the same capacity.

Vancouver, BC-based Zinc8 Energy Solutions is advancing industrial-scale installations of this burgeoning battery technology that is decoupling the energy produced and the power delivered to customers in the U.S. and Canada.

"By decoupling the linkage between power and energy, and using low-cost, abundant materials, our system is capable of reducing its capital cost dramatically for longer-duration applications," according to Zinc8.

Zinc8's groundbreaking energy storage system won the New York Power Authority (NYPA) Innovation Challenge in 2020, resulting in a contract for a large installation of the system in New York State.

"This is the thing that's changed our company – going from having some interest, but nobody thinking that zinc-air was ready – to our phones ringing nonstop from big utilities and globally connected companies around the world," said Zinc8 Energy Solutions President and CEO Ron MacDonald.

This includes calls from utilities and developers wanting to use Zinc8 systems for long-duration storage of renewable energy to a leading cloud storage provider that is testing the system as a reliable and resilient storage technology that can provide megawatt-scale standby power for the critical data stored.

"The continued growth in cloud data centers globally could greatly benefit from our long-duration energy storage technology and support the commitments to a reduced carbon footprint for operators of large-scale data centers," said MacDonald.

And with zinc being one of the most common metals on Earth, it offers an ideal solution for diversifying grid-scale energy storage and the mined materials needed to achieve the increasingly ambitious targets for phasing out ICE automobiles in favor of EVs charged with green energy. DMN

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