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CSIS BRIEFS

Rebuilding U.S. Zinc Capacity in an Era of Global Competition

By Gracelin Baskaran and Meredith Schwartz

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THE ISSUE

Zinc ranks as the fourth-most widely used metal worldwide. In addition to its primary application in steel galvanization, refining zinc also produces gallium and germanium—key inputs for advanced semiconductors and defense technologies. However, amid falling ore grades and limited exploration, the United States remains heavily dependent on zinc imports. Once a global hub for zinc processing, the United States now lacks sufficient refining capacity, importing over 70 percent of its refined zinc. There is an opportunity to rebuild domestic, vertically integrated zinc supply chains and reduce reliance on China, but this will demand deliberate action. Bolstering U.S. resilience will require scaling up domestic mining and refining, strategically deploying tariffs, encouraging private investment, promoting price stability, and deepening partnerships with allied nations.

INTRODUCTION

Zinc is the fourth-most produced and consumed metal globally, after iron, aluminum, and copper, with an annual market value of $40 billion.[1] Its role as a galvanizing agent—protecting iron and steel from corrosion—makes it indispensable to industries like construction, infrastructure, and manufacturing. Thanks to its low melting point, malleability, and wear resistance, zinc is a uniquely suited material for galvanizing steel.[2] In addition, the refining of zinc yields two other critical minerals: germanium and gallium, neither of which the United States produces in significant quantities.[3] Production of germanium, an important semiconductor material, is dominated by China, which in 2023 accounted for 68 percent of global production, and in December 2024, China halted germanium exports to the United States.[4] Gallium—another important semiconductor material, derived from either zinc or bauxite—is not produced domestically in the United States and was similarly impacted by China's export restrictions.

THE DECLINE OF THE U.S. ZINC INDUSTRY

The United States was once the largest zinc processor in the world, with 19 processing plants in operation.[5] At the start of the Cold War, the U.S. government raised concerns that reserves of strategic materials, including zinc, would fall short in the event of conflict. The United States enacted a strategy to boost domestic and allied production of zinc by lowering existing tariffs and employing Defense Production Act programs, including government purchases, attractive loan agreements, and tax incentives. The Defense Minerals Exploration Administration also offered aid for zinc deposit exploration activities.[6] These government policies successfully bolstered U.S. supply chains and zinc supply for the industrial base.

By the late 1950s, an excess supply of zinc prompted the government to increase stockpiles of domestic and foreign-produced material while initiating quotas and

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barter agreements abroad to reduce foreign output. However, by the late 1960s and 1970s, as incentive programs ended and foreign mine production decreased, domestic processing facilities struggled to source adequate quantities of feedstock without access to foreign ore. The U.S. government began pulling back its involvement in the materials industry and released government stockpiles, creating market volatility and demand uncertainty. Significant domestic processing capacity closed permanently, and investment in new construction dwindled.[7] By the 1980s, the remaining U.S. processing infrastructure was largely outdated and in desperate need of modernization.

Today, the United States produces a little over 6 percent of the world's zinc, compared with China's 33 percent.[8] Most of this production, nearly 70 percent, takes place at the Red Dog mine in Alaska, owned by Canada's Teck Resources. As the top-producing zinc mine in the world, Red Dog can attribute its success to high ore grades and mill rates and reasonably low production costs.[9] Compared with many other mining operations in the United States, Red Dog operates profitably, with total production costs of 93.8 cents per pound, well under current zinc prices of 133.1 cents per pound.[10] Red Dog has led global zinc mining, producing 555,600 metric tons of zinc in 2024 alone, nearly 5 percent of all zinc produced globally last year.[11] However, production is expected to decrease over the coming years as ore depletes and degrades. Zinc production at Red Dog is forecasted to drop 7 percent in 2025, and the mine is projected to close operations in 2031.[12] Nearby deposits are being explored to extend the life of the mine, but the market outlook for new U.S. mines coming online is challenging. Two U.S. zinc mines in Tennessee were taken offline in 2023 due to weak prices and high inflation.[13]

South32's Hermosa project, located in the Patagonia Mountains of southern Arizona, is a major mining development that includes the Taylor and Clark deposits—both vital to securing U.S. supplies of key minerals.[14] The Taylor deposit contains an estimated 153 million tons of zinc-lead-silver sulfide resources, with average grades of 3.53 percent zinc, 3.83 percent lead, and 77 grams per ton of silver.[15] A feasibility study projects an initial mine life of around 28 years, with production set to begin in the latter half of fiscal year 2027.[16] Positioned above Taylor, the Clark deposit features zinc-manganese-silver oxide mineralization and has the potential to produce battery-grade manganese. As of early 2025, Hermosa was the only advanced U.S. mining project capable of producing both zinc and manganese—minerals the federal government recognizes as critical. The International Zinc Association projects growth of just under 700,000 metric tons per year in consumption of zinc by 2030, largely due to demand from the automotive sector.[17]

BOTTLENECKS FACING THE U.S. ZINC SECTOR

The limited level of domestic exploration in the United States has impeded the development of new zinc mines. Over the past 25 years, the United States has accounted for only 5.9 percent of global zinc exploration, while South America has drawn an average of 30.4 percent (Figure 1). This exploration gap has stalled the discovery and development of new U.S. zinc resources, intensifying supply risks—especially with the country's largest zinc mine scheduled to shut down in six years. In 2024, U.S. zinc exploration totaled $32.5 milllion—the second-lowest amount since 2017.[18]

Declining domestic zinc ore grades is a significant challenge facing Western producers. When mining began at the Red Dog Mine, the main pit ore body had zinc grades as high as 20.5 percent.[19] Today, those grades have declined to 13.42 percent—still the highest in the country. In comparison, the average zinc grade across the 12 largest new U.S. development projects is just 5.81 percent.[20]

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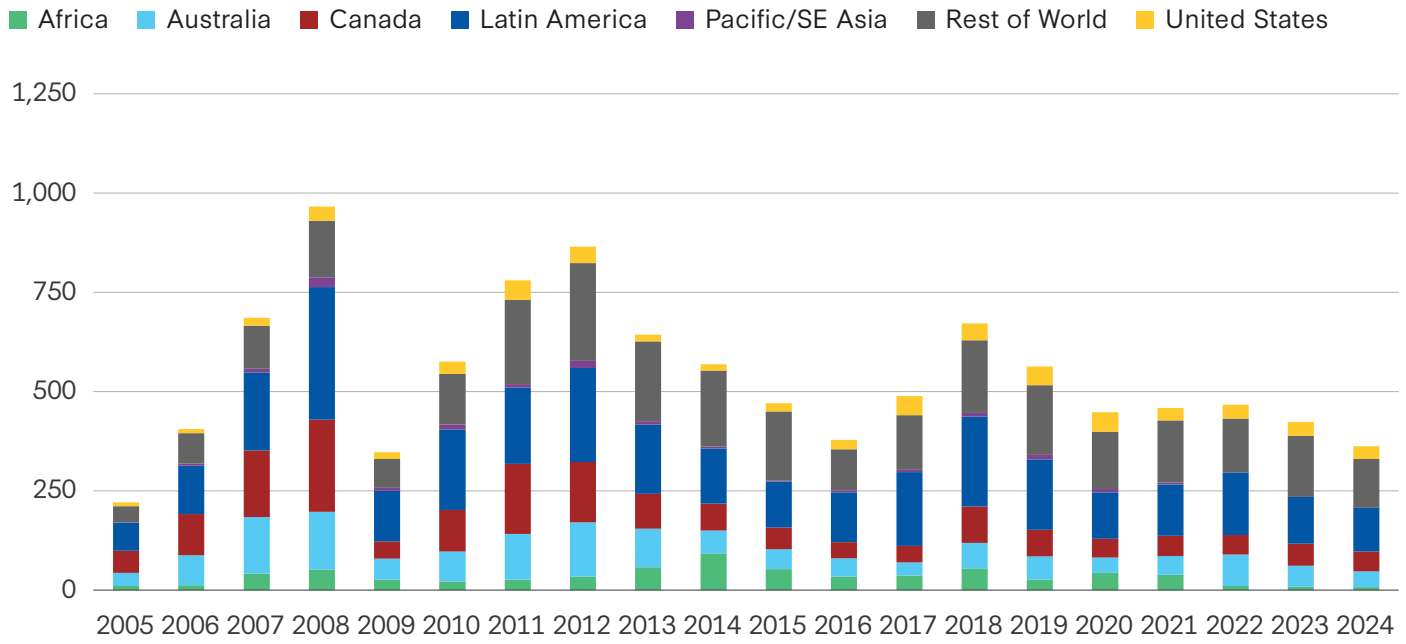
Table 1: U.S. Zinc Ore Grades

Mine	Location	Ore Grade of Total Reserves and Resources (%)	Development Stage
Red Dog	Alaska	13.42	Expansion
Hermosa	Arizona	3.11	Feasibility Complete
Nicolet	Wisconsin	9.80	Reserves Development
Su Claims	Alaska	10.00	Reserves Development
Lik	Alaska	8.10	Prefeas/Scoping
Upper Kobuk Mineral Projects	Alaska	0.57	Feasibility Complete
Santa Rosa	California	8.80	Target Outline
West Desert	Utah	3.83	Prefeas/Scoping
Greens Creek	Alaska	3.09	Operating
East Tennessee Mines	Tennessee	3.90	Operating
Red Mountain	Alaska	3.89	Advanced Exploration
Empire State	New York	2.72	Operating
Palmer	Alaska	4.27	Prefeas/Scoping

Note: Blue indicates projects under early-stage development.

Source: "S&P Global Capital IQ database," S&P Global.

Figure 1: Global Zinc Exploration Budget 2005-2024 (USD, millions)



Source: "S&P Global Capital IQ database," S&P Global.

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Even with a new domestic zinc source expected to come online from Arizona, the United States remains heavily dependent on foreign suppliers for refined zinc due to a critical lack of domestic refining capacity. In 2024, the United States imported 73 percent of the refined zinc it used.[21] Although domestic production of zinc concentrate reached nearly 750,000 tons, the U.S. exported 580,000 tons of that ore and imported 600,000 tons of refined zinc to satisfy demand.[22] Today, the United States relies heavily on Canada and Mexico as partners in the zinc supply chain. Between 2020 and 2023, the United States imported 59 percent of its refined zinc from Canada and 16 percent from Mexico.[23] However, the trade policies of U.S. President Donald Trump's administration toward Canada, particularly the 25 percent tariff levied on Canadian imports, could significantly disrupt this decades-old trade relationship. In March 2025, Teck CEO Jonathan Price noted that the company is looking to sell its zinc to Asia instead of the United States to avoid U.S. tariffs.[24]

At the same time, shifting global market conditions are creating new challenges. Zinc prices are down nearly 33 percent from 2022, and Chinese consumption has fallen. This has contributed to three consecutive years of reduced mine production. The global zinc ore deficit was estimated at 164,000 metric tons in 2024.[25] As a result, refineries do not have adequate access to feedstock to operate at scale. Refining charges—the fees paid by miners to processors to turn raw ore into metal—have slumped.[26] Even Chinese smelting operations are struggling to find zinc feedstock and operate at economically viable prices. The shortage makes it especially challenging for the United States and other market-led economies to invest in additional refining capacity.

Without domestic zinc refining capacity, the United States will continue to export its mined zinc and import refined metal, primarily from Canada and Mexico. While this North American–led supply chain faces fewer risks than many other critical mineral supply chains controlled by adversaries, the Trump administration's tariff policies may create new challenges for the zinc supply chain as well as the U.S. steel industry, which requires zinc for galvanizing, and the semiconductor industry, which requires germanium.

DRIVERS OF ZINC DEMAND

STEEL INDUSTRY

Strengthening the domestic steel industry has been a central priority for the Trump administration, given its significance to both economic competitiveness and national defense. Tariffs have been the administration's primary instrument for supporting domestic industry, including the imposition of 25 percent tariffs on all steel and aluminum imports without exceptions.[27] While these actions aim to boost domestic steel production, they may have unintended effects on the zinc supply that the galvanized steel industry relies on. Roughly 60 percent of the world's zinc is used to galvanize steel.[28]

The United States is the fourth-largest producer of steel in the world following China, India, and Japan.[29] In 2024, the United States produced 79.5 million metric tons of steel, compared with China's 1 billion metric tons.[30] Only 5–6 percent of domestically produced U.S. steel is galvanized, compared with 17 percent of globally manufactured steel. The deficit in domestic steel production is reflected in the fact that hot-dipped galvanized steel is the United States' most imported flat product.[31]

The demand for galvanized steel is precipitously rising, with a compounded annual growth rate of 6.9 percent over the next six years, driven by the nuclear, energy, and automotive industries.[32] Power transmission and energy infrastructure are regularly exposed to harsh environments and weather conditions, necessitating galvanized steel suited to withstand corrosion and uphold structural integrity.[33] An extensive, durable, and efficient electric grid that can handle the power demands of new artificial intelligence data centers will rely on transformers, power cables, and substations made of galvanized steel. Additionally, as the United States looks to transform the nuclear energy industry with the next generation of commercial reactors, this nuclear infrastructure requires corrosion-resistant steel that meets high safety standards. Galvanized steel is a key input for strategic industries, but reliable access to zinc is necessary to sustain the sector.

SEMICONDUCTOR INDUSTRY

Two semiconductor materials—gallium and germanium—are produced as by-products of zinc processing. These materials are increasingly important metals for the next generation of semiconductors, especially those designed for defense applications.

Gallium is used to produce gallium nitride and gallium arsenide high-performance chips, which offer higher speed, lower resistance, and lower production costs compared with alternatives.[34] Gallium is an indispensable, non-substitutable material for the defense industry's next generation of high-power, high-frequency electronic devices. Gallium-containing chips

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can be found in mobile phones, automotives, satellites, and lidar sensors. The market for Gallium nitride chips is expected to grow 25 percent annually through 2030, with defense applications driving this increase.

Germanium has an immense advantage over other common semiconductor materials when it comes to electron mobility.[35] Electrons move nearly three times faster through germanium than silicon. Faster electrons mean faster device performance.[36] Chipmakers are now experimenting with using germanium in the current-carrying channels in silicon semiconductor wafers to move electron currents at faster rates. Such chips, made with germanium channels placed on silicon wafers, are known as complementary-metal-oxide-semiconductor (CMOS) circuits.[37] These circuits are used in quantum computers, which are millions of times faster than classic computers.[38]

Producing gallium and germanium from zinc is technically challenging, expensive, and energy intensive. The germanium content in zinc ores must be high in order to make extraction economically viable, as only a fraction of the germanium contained in zinc concentrate can be successfully extracted with current techniques.[39] Globally, less than 5 percent of the germanium contained in zinc concentrate reaches refineries with germanium extraction and production capabilities, and as little as 3 percent is successfully recovered.[40]

The United States currently produces no gallium and only small amounts of germanium from zinc deposits in Alaska and smelting operations in Tennessee. Most zinc concentrates from Red Dog are sent to Teck Resources' processing operations in British Columbia, Canada, for germanium to be separated, extracted, and refined. Some new projects are in the pipeline to develop these capabilities domestically but have yet to materialize. Nyrstar, a subsidiary of Singaporean Trafigura, announced a $150 million investment to expand its existing zinc operations in Tennessee and add a gallium and germanium processing facility.[41] However, the project has yet to secure investor funding, and the company has faced market challenges that led it to temporarily suspend zinc mining operations in October 2023.

For now, the United States will remain reliant on imports of gallium and germanium to support its semiconductor industry. Continued reliance on foreign adversaries for significant volumes of gallium and germanium poses untenable national security risks, especially in light of Chinese export bans targeting these materials. While Canada is poised to be a significant North American ally in supporting these semiconductor material supply chains, new tariffs targeting Canadian imports threaten the future of this partnership.

INTERNATIONAL ZINC PRODUCTION LANDSCAPE

China is the world's leading zinc producer and consumer. In 2023, China accounted for 51.3 percent of the world's zinc consumption.[42] It has ownership stakes in several of the world's highest-yielding zinc mines, located in China and Russia (Table 1). As part of its broader Belt and Road Initiative to secure dominance over global mineral supply chains, China has acquired mining assets across a wide range of countries, including Iran, Indonesia, Mongolia, Eritrea, and even Australia. Its investment strategy appears to prioritize high-grade ore deposits, such as Mongolia's Tumurtiin Ovoo, which boasts ore grades exceeding 13 percent, comparable to Alaska's Red Dog mine. China also holds controlling interests in major Western mines, including a majority stake in Australia's Dugald River mine, which ranks seventh globally in production and thirteenth in reserves. This combination of substantial domestic reserves and global ownership enables China to maintain its leadership in zinc production—a position that is unlikely to be challenged soon, especially as it controls four of the world's top ten zinc development projects by reserve size. These include the Izok Lake property in Nunavut, for which the Government of Canada is committing over $40 million to develop key road infrastructure to support the Nunavut mining sector and the Izok Lake project.[43] China also has invested in the Yukon region, with reportedly globally significant reserves and potential for germanium and gallium extraction.[44]

China continues to reinforce its control over global zinc supply chains through its dominance in smelting and refining. The country owns four of the world's top 10 zinc refineries, which have a combined annual smelting capacity of over 1.3 million tons.[45] In 2023, China was the largest importer of zinc ore, securing 36.4 percent of the world's zinc exports as feedstock for refineries.[46] This ore primarily originated in Australia (24.5 percent), Peru (19.0 percent), South Africa (9.0 percent), and Bolivia (8.3 percent). This refined zinc supports China's steel industry, the largest in the world, as well as its command over gallium and germanium supply chains.

However, China is not the only country with significant zinc operations. India and Brazil are also major players in mined zinc production. India's Hindustan Zinc owns three of the world's top 15 zinc-producing mines. The world's fifth-largest zinc smelter is also located in India.

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Brazil's Nexa Resources, likewise, owns two of the world's highest-producing zinc mines and manages Latin America's largest zinc smelter, located in Peru.

Australia and Peru have strong potential to expand their roles in the zinc supply chain. Australia holds the largest zinc reserves globally—28 percent of the world's total—but accounted for just 9 percent of global production in 2023.[47] Over 65 percent of Australia's zinc exports are shipped to China for refining.[48] Peru, ranked fourth in global zinc reserves, has a largely undeveloped resource base. Investment in mining has been constrained by rising social unrest and growing tensions between mining companies and Indigenous communities, which have challenged the sector's social license to operate. Addressing these issues will be essential for Peru to emerge as a major force in global zinc production.

The United States has significant opportunities to work with international partners to establish zinc supply chains outside China. However, market challenges related to price volatility, uneven distribution of midstream capacity, and Chinese overproduction must be addressed to create a more enabling environment for U.S. investment in zinc operations abroad. Deepening ties with partner nations like India, Australia, Brazil, and Peru will be essential to building a vertically integrated supply chain as well as countering China's influence in these economies.

Table 2: World's Top-Producing Zinc Mines

Property	Commodity Production (mt)	Location	Primary Owners	Country Ownership
Red Dog	555,600	United States	Teck Resources Limited	Canada
Rampura Agucha	514,000	India	Hindustan Zinc Limited	India
Aripuana	316,000	Brazil	Nexa Resources SA	Brazil
Sihuan Zinc and Germanium	300,000	China	Chengtun Mining Group	China
Mount Isa Zinc	287,200	Australia	Glencore PLC	Switzerland
Kazzinc Consolidated	269,000	Kazakhstan	Kazzinc Ltd.	Switzerland
McArthur River	259,700	Australia	Glencore PLC	Switzerland
Yauli	166,900	Peru	Volcan Compañía Minera	Peru / Canada
Dugald River	163,588	Australia	MMG Limited	China
Gamsberg	147,000	South Africa	Vedanta Limited Exxaro Resources Limited	India / South Africa
Sindesar Khurd	146,000	India	Hindustan Zinc Limited	India
Vazante	140,700	Brazil	Nexa Resources SA	Brazil
Zawar Group	115,000	India	Hindustan Zinc Limited	India

Source: "S&P Global Capital IQ database," S&P Global.

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Late-stage zinc deposits—those closest to production—are the most likely to be developed in the near term. As Table 2 shows, Chinese firms control four of the largest of these projects based on reserve size. Importantly, none of these deposits are located in China; instead, Chinese companies hold significant stakes in zinc assets in Russia, Iran, Peru, and even Canada.

Table 3: World's Largest Zinc Reserves in Late-Stage Development, 2024

Property	Contained Reserves and Resources (mt)	Location	Owners
Kholodninskoe	21,200,000	Russia	MBC Resources Ltd. (metropol)
Mehdiabad	16,504,000	Iran	KDD Group (venturer), 45.6% ITOK GROUP (venturer), 24.5% MB Holding Company LLC (venturer), 24.5% Private interest (venturer), 5.4%
Citronen	3,990,000	Greenland	Skylark Minerals Limited
Hilarion	3,662,900	Peru	Nexa Resources Perú SAA (owner), 100% Compañía Minera Gaico SA (fractional) Private interest, China (fractional)
Cirque	3,120,000	Canada	Korea Zinc Company, Ltd. Teck Resources Limited
Pine Point	2,439,000	Canada	Osisko Metals Incorporated Appian Capital Advisory LLP
Khnaiguiyah	2,061,600	Saudi Arabia	Alara Resources Limited
Izok Lake	1,855,000	Canada	MMG Limited
Bamnia Kalan	1,390,000	India	Hindustan Zinc Limited
Kudz Ze Kayah	1,300,400	Canada	BMC (UK) Limited

Source: "S&P Global Capital IQ database," S&P Global.

The midstream segment of the supply chain has two stages. Smelting is the first stage of processing zinc ore into refined, high-purity zinc that can be used for industrial purposes. It is also the stage where gallium and germanium can be extracted as by-products. Zinc refining is the final stage in the midstream process. China cements its dominance of the zinc supply chain in these midstream stages of the supply chain.

While China owns and operates mines around the world, its smelting and refining capacity is concentrated at home. China owns five of the world's top smelters and four of the

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world's top zinc-producing refineries. With global refined zinc production estimated at 13.5 million metric tons in 2022, these four Chinese refineries alone account for nearly 9 percent of global capacity. With respect to the world's 30 largest zinc refineries, China accounts for 37.5 percent of global capacity, and the United States accounts for less than 2 percent.

Table 4: World's Top Global Zinc Smelters

Property	Production Capacity (mt)	Location	Owners	Country Ownership
Nandan Smelter	370,000	China	Nanfang Non-Ferrous Metals Co., Ltd.	China
Cajamarquilla Smelter	350,000	Peru	Nexa Resources SA	Luxembourg
Kokkola Smelter	315,000	Finland	Boliden AB	Sweden
Valleyfield Smelter	300,000	Canada	Noranda Income Fund	Canada
Doswada Smelter	300,000	India	Hindustan Zinc Limited	India
Risdon Smelter	280,000	Australia	Trafigura Group Pte. Ltd.	Singapore
Dariba Smelter	240,000	India	Hindustan Zinc Limited	India
Huludao Smelter	200,000	China	Huludao Hongyue Group Co., Ltd.	China
Khnaiguiyah Smelter	200,000	Saudi Arabia	Ajlan & Bros Holding Group (venturer), 50% Moxico Resources PLC (venturer), 50%	United Kingdom
Tenglong Smelter	150,000	China	Private interest, China	China
Lanping Smelter	140,000	China	Yunnan Jinding Zinc Co., Ltd.	China
Xingan Smelter	130,000	China	Inner Mongolia Xing'an Copper & Zinc Smelting Co., Ltd.	China
Verkhny Ufalei Smelter	120,000	Russia	Russian Copper Company	Russia

Source: "S&P Global Capital IQ database," S&P Global.

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Table 5: World's Top Zinc Refineries

Property	Production Capacity (mt)	Location	Owners
Onsan Refinery	660,000	South Korea	Korea Zinc Company, Ltd.
San Juan de Neiva Refinery	520,000	Spain	Glencore PLC
Sukpo Refinery	400,000	South Korea	Young Poong Co., Ltd.
Nanfang Refinery	370,000	China	Nandan County Nanfang Non-Ferrous Metals Co., Ltd.
Mianxian Refinery	360,000	China	Hanzhong Zinc Industry Co., Ltd.
Kokkola Refinery	315,000	Finland	Boliden AB
Trail Refinery	310,000	Canada	Teck Resources Limited
Budel-Dorplein Refinery	300,000	Netherlands	Trafigura Group Pte. Ltd.
Sichuan Sihuan Refinery	300,000	China	Chengtun Mining Group Co., Ltd.
Shuikoushan Refinery	300,000	China	Zhuzhou Smelter Group Co., Ltd.

Note: This table uses data from 2022 and 2023, based on the most recent year data is available.

Source: "S&P Global Capital IQ database," S&P Global.

RECOMMENDATIONS TO STRENGTHEN U.S. ZINC SUPPLY CHAINS FOR THE DOMESTIC STEEL AND SEMICONDUCTOR INDUSTRIES

1. **Utilize tariffs judiciously and strategically.**

   Tariffs risk disrupting the supply of refined zinc and germanium to the United States. In March 2025, Teck CEO Jonathan Price indicated the company may redirect its zinc exports to Asian markets to avoid U.S. tariffs.[49] Given that Teck operates one of the world's largest fully integrated zinc and lead refining facilities and serves as a key supplier of refined zinc and germanium to the United States, this trade diversion would have significant economic implications—particularly for the domestic steel and semiconductor industries. Teck's Trail Operations in British Columbia is among the world's leading producers of germanium, a critical input for semiconductor manufacturing. In 2023, Canada provided 25 percent of U.S. germanium imports, with Teck as the sole Canadian source.[50] Canada's role became even more critical following China's ban on germanium exports to the United States in December 2024. Access to zinc also remains essential for the U.S. steel industry, particularly for galvanizing steel used in vital infrastructure such as nuclear reactors, electric grid systems, and defense technologies—much of which is sourced from Canada.

   The United States should be exploring ways to expand its domestic midstream capacity for a variety of minerals, including zinc. But these projects take years to plan, build, operate, and reach capacity. In the meantime, the United States will remain dependent on imported zinc. Tariffs on refined

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zinc and germanium imports from Canada will, at best, increase the cost of inputs and, at worst, displace imports to other markets. Tariff exemptions for refined zinc are a common-sense solution that supports competitive U.S. steel and semiconductor industries.

Additionally, the proposed strategic tariff exemptions cover only specific minerals and do not extend to the construction materials required to build mines and processing plants. These tariffs risk rendering domestic projects—like the Hermosa zinc mine—economically unfeasible. To support U.S. mining development, exemptions should be extended across the entire mining ecosystem.

2. **Leverage tax credits, grants, and incentives to boost domestic capabilities.**

The Trump administration has introduced its strategy to strengthen U.S. midstream capacity for critical minerals through an executive order titled "Immediate Measures to Increase American Mineral Production."[51] The initiative includes beneficial steps such as streamlining permitting processes and expanding access to federal lands. However, attracting investment for new zinc mining and refining projects remains difficult due to depressed smelting prices and market distortions caused by China's overproduction. To make these ventures more attractive to the private sector, further incentives are necessary. Grant programs like the Defense Production Act Title III program can play a crucial role by offering essential up-front capital. Production and investment tax credits, like those modeled in the Inflation Reduction Act, offset costs for producers and can help incentivize building domestic midstream capabilities.

For example, the IRA Section 45X Production Tax Credit provides a 10 percent credit for the costs incurred during production of processed critical minerals, including high extraction and material costs.[52] Notably, this credit does not phase out for critical minerals projects, meaning the credit could be available to support domestic producers well into the future. This credit is significant to projects that are vertically integrating supply chains by sending feedstock from allied mining operations to U.S. mineral refineries. The continuation of this credit could be crucial to incentivizing additional domestic zinc projects that process ore from both domestic mines as well as allied mines in Australia or Peru.

3. **Use price support mechanisms to de-risk investments in the zinc supply chain.**

Critical mineral price volatility is one of the greatest market challenges for the sector. Timelines for mining investments are long, meaning if commodity prices crash, a project deemed economic at the start of the project may no longer be economic by the time it is operational. While prices appear to be recovering amid reduced production and high demand, there is no guarantee they will remain on a positive trajectory.[53] China is overproducing refined zinc, making it highly challenging for new rival projects to enter. The United States should respond and support its domestic industry by implementing price floors for both zinc ore and refined zinc. With a U.S. government-imposed price floor, the government would pay U.S. mining companies the difference should market prices fall beneath a minimum price threshold. This guarantee ensures strategic projects can continue operating at cost, which can help prevent mine closures and mass layoffs like those at the Sibanye-Stillwater palladium and platinum mine in Montana in 2024.[54] Price floors also reduce risks for investors, who must wait years before seeing returns. In a high-risk industry like mining, mitigating the risks of price volatility can encourage investors in an industry that often struggles to attract private financing.

4. **Partner with strategic allies.**

China does not dominate zinc supply chains as it does supply chains for many other critical minerals. Countries such as India, Brazil, and Australia have substantial zinc reserves, production capabilities, and supporting infrastructure, making them strong competitors. The United States has the potential to build vertically integrated zinc supply chains and reduce dependence on China, but doing so will require stronger international collaboration and a more proactive U.S. approach to minerals-focused commercial diplomacy.

Although Australia is a close U.S. ally, it currently exports 65 percent of its zinc to China, largely due to China's midstream processing capacity and will-

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ingness to operate in economically unfavorable but strategically advantageous conditions. Emerging partners like Peru are also keen to strengthen ties with the United States through formal trade agreements and memorandums of understanding. However, the United States has historically taken a hands-off approach to minerals supply chains, allowing China to consolidate control over key stages of zinc extraction, refining, and downstream use, including in steel production, as well as the processing of elements like gallium and germanium.

To shift this dynamic, U.S. institutions such as the Export-Import Bank of the United States and the International Development Finance Corporation should take a more active role in strategic mining regions. They can help reduce investment risk, foster government-to-business connections, and negotiate offtake to expand U.S. access to high-quality mineral projects abroad. ■

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FreightCar America, Ex. 1028
IPR2025-01047

ENDNOTES

1. World Economic Forum, "Zinc Is Critical for the Low-Carbon Economy. Here's Why," April 13, 2022, https://www.weforum.org/stories/2022/04/zinc-low-carbon-economy-construction/.
2. Reuters, "Column: China's zinc imports reflect shifting market dynamics," *MINING.COM* (blog), June 13, 2024, https://www.mining.com/web/column-chinas-zinc-imports-reflect-shifting-market-dynamics/.
3. The Geospatial Platform, "Germanium Deposits in the United States," https://www.sciencebase.gov/catalog/item/5e87562a82cee42d133ff6b4; and U.S. Geological Survey, *Mineral Commodity Summaries 2025: Gallium* (Reston: U.S. Geological Survey, March 2025), 74-75, https://doi.org/10.3133/mcs2025.
4. Christopher Cytera, "Gallium, Germanium, and China – The Minerals Inflaming the Global Chip War," The Center for European Policy Analysis, August 8, 2023, https://cepa.org/article/china-gallium-and-germanium-the-minerals-inflaming-the-global-chip-war/.
5. Gary A. Campbell, Anil Jambekar, and Brian Frame, "Zinc Processing in the USA: An Analysis of a Declining Industry," *Resources Policy*, volume 12, no. 4 (December 1, 1986): 317-34, https://doi.org/10.1016/0301-4207(86)90004-8.
6. "Historical Files from Federal Government Mineral Exploration-Assistance Programs, 1950 to 1974," U.S. Geological Survey, https://pubs.usgs.gov/ds/1004/ds1004_proginfo.htm.
7. Campbell, Jambekar, and Frame, "Zinc Processing in the USA."
8. U.S. Geological Survey, *Mineral Commodity Summaries 2024: Zinc* (Reston: U.S. Geological Survey, January 2024), 202-203, https://doi.org/10.3133/mcs2024.
9. Shane Lasley, "Red Dog is producing 5% of world's zinc," North of 60 Mining News, October 25, 2024, https://www.miningnewsnorth.com/story/2024/10/25/news-nuggets/red-dog-is-producing-5-percent-of-worlds-zinc/8767.html.
10. "CIQ Pro: Red Dog | Mine Economics Modeled Product Costs," S&P Global, https://www.capitaliq.spglobal.com/web/client?auth=inherit#metalsAndMiningProperty/modeledProductCosts?ID=24851; and "CIQ Pro: Price Chart," S&P Global, https://www.capitaliq.spglobal.com/web/client?auth=inherit#industry/priceChart.
11. "CIQ Pro: Red Dog | Production," S&P Global, https://www.capitaliq.spglobal.com/web/client#metalsAndMiningProperty/annualProduction?ID=24851.
12. Ibid.
13. Reuters, "Nyrstar to suspend operations at two US zinc mines," *MINING.COM* (blog), November 1, 2023, https://www.mining.com/web/nyrstar-says-to-suspend-operations-at-two-us-zinc-mines/.
14. "Hermosa," South32, https://www.south32.net/what-we-do/our-locations/americas/hermosa.
15. "Hermosa Project," South32, https://www.south32.net/what-we-do/our-locations/americas/hermosa/about-hermosa.
16. "Hermosa Base Metals Project," NS Energy, January 21, 2022, https://www.nsenergybusiness.com/projects/hermosa-base-metals-project/.
17. Natasha Porter, "Zinc demand expected to grow this decade despite soft demand, supply challenges, IZA director says: LME Week," *Fastmarkets* (blog), October 9, 2024, https://www.fastmarkets.com/insights/zinc-demand-expected-to-grow-this-decade-despite-soft-demand-supply-challenges-iza-director-says-lme-week/.
18. "CIQ Pro: Zinc Exploration Budget Trends," S&P Global, https://www.capitaliq.spglobal.com/web/client?auth=inherit#industry/CommodityExploBudgetTrends.
19. "Red Dog Mine Closure and Reclamation Plan," Alaska.gov, 2004, https://dnr.alaska.gov/mlw/mining/large-mines/red-dog/pdf/sdb1.pdf.
20. "CIQ Pro: Zinc Metals and Mining Projects," S&P Global, https://www.capitaliq.spglobal.com/web/client?auth=inherit#industry/miningProjects.
21. U.S. Geological Survey, *Mineral Commodity Summaries 2025: Zinc* (Reston: U.S. Geological Survey, March 2025), 202-203, https://doi.org/10.3133/mcs2025.
22. Ibid.
23. Ibid.
24. Reuters, "PDAC: Teck plans to sell to Asia to avoid US tariffs," *MINING.COM* (blog), March 5, 2025, https://www.mining.com/web/teck-ceo-says-miner-could-sell-to-asia-to-avoid-trumps-new-tariffs/.
25. Reuters, "Column: Zinc facing supply deficit as mine output falls again," *MINING.COM* (blog), October 9, 2024, https://www.mining.com/web/column-zinc-facing-supply-deficit-as-mine-output-falls-again/.
26. Reuters, "Column: China's zinc imports reflect shifting market dynamics," *MINING.COM* (blog), June 13, 2024, https://www.mining.com/web/column-chinas-zinc-imports-reflect-shifting-market-dynamics.
27. David E. Bond et al., "President Trump Expands Steel and Aluminum Tariffs to All Countries; Effective March 12, 2025," White & Case, February 17, 2025. https://www.whitecase.com/insight-alert/president-trump-expands-steel-and-aluminum-tariffs-all-countries-effective-march-12.
28. "Zinc Facts," Natural Resources Canada, https://natural-resources.canada.ca/minerals-mining/mining-data-statistics-analysis/minerals-metals-facts/zinc-facts.
29. Niccolo Conte, "Ranked: The World's Biggest Steel Producers, by Country," Visual Capitalist, May 19, 2023, https://www.visualcapitalist.com/biggest-steel-producers-country/.
30. worldsteel, "December 2024 crude steel production and 2024 global crude steel production totals," press release, January 24, 2025, https://worldsteel.org/media/press-releases/2025/decembe

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FreightCar America, Ex. 1028
IPR2025-01047

r-2024-crude-steel-production-and-2024-global-totals/.

31. "US steel imports rise for third time in a decade," MEPS International, January 16, 2025, https://mepsinternational.com/gb/en/news/us-steel-imports-rise-for-third-time-in-a-decade.

32. Grand View Research, *Galvanized Steel Market Size, Share & Trends Analysis Report By End-use (Automotive, Building & Construction, Appliances), By Region (North America, Europe, Asia Pacific), And Segment Forecasts, 2025 - 2030* (San Francisco: Grand View Research), https://www.grandviewresearch.com/industry-analysis/galvanized-steel-market-report.

33. "Nuclear and Energy," Joseph Ash Galvanizing, https://www.josephash.co.uk/sectors/nuclear-and-energy/.

34. Sujai Shivakumar, Julia Yoon, and Tisyaketu Sirkar, "Gallium Nitride: A Strategic Opportunity for the Semiconductor Industry," CSIS, *Commentary*, May 20, 2024, https://www.csis.org/analysis/gallium-nitride-strategic-opportunity-semiconductor-industry.

35. Gérard Ghibaudo and Quentin Rafhay, "Electron and Hole Mobility in Semiconductor Devices," In *Wiley Encyclopedia of Electrical and Electronics Engineering* (Hoboken: John Wiley & Sons, Ltd, September 2014), 1-13, https://doi.org/10.1002/047134608X.W3148.pub2.

36. Ibid.

37. Ibid.

38. Shane Lasley, "America's largest critical minerals mine," North of 60 Mining News, March 4, 2022, https://www.miningnewsnorth.com/story/2022/03/04/in-depth/americas-largest-critical-minerals-mine/7274.html.

39. Madhav Patel and Athanasios K. Karamalidis, "Germanium: A review of its US demand, uses, resources, chemistry, and separation technologies," *Separation and Purification Technology*, volume 275 (November 15, 2021), https://doi.org/10.1016/j.seppur.2021.118981.

40. Ibid.

41. Casey Williams, "Nyrstar plans expansion of Clarksville plant with $90 million germanium, gallium processing facility," Clarksville Now, July 7, 2022, https://clarksvillenow.com/local/nyrstar-plans-expansion-of-clarksville-plant-with-90-million-germanium-gallium-processing-facility/.

42. Lu Tong et al., "Mapping the anthropogenic zinc cycle in China from 2000 to 2021: A dynamic material flow analysis," *Resources Policy*, volume 99 (December 1, 2024), https://doi.org/10.1016/j.resourpol.2024.105417.

43. Rose Ragsdale, "Northern Zinc-Rich Projects Get Boost," North of 60 Mining News, September 26, 2020, https://www.miningnewsnorth.com/story/2019/10/01/news/northern-zinc-rich-projects-get-boost/5934.html.

44. Blair McBride, "Update Bumps Zinc Resource Four-Fold for Fireweed Metals' Macpass Project in Yukon," *MINING.COM* (blog), September 5, 2024, https://www.mining.com/update-bumps-zinc-resource-four-fold-for-fireweed-metals-macpass-project-in-yukon/.

45. S&P Global Capital IQ database, S&P Global, https://www.capitaliq.com.

46. "Zinc Ore," The Observatory of Economic Complexity, https://oec.world/en/profile/hs/zinc-ore.

47. U.S. Geological Survey, *Mineral Commodity Summaries 2024: Zinc*.

48. "Zinc Ore," The Observatory of Economic Complexity.

49. Reuters, "PDAC: Teck plans to sell to Asia to avoid US tariffs," *MINING.COM* (blog).

50. "Globe says Teck has what U.S. needs: germanium," Stockwatch, January 20, 2025, https://www.stockwatch.com/News/Item/Z-C%21TECK-3643060/C/TECK.

51. "Immediate Measures to Increase American Mineral Production," The White House, March 20, 2025, https://www.whitehouse.gov/presidential-actions/2025/03/immediate-measures-to-increase-american-mineral-production/.

52. Gracelin Baskarn et al., *Critical Minerals and the Future of the U.S. Economy* (Washington, DC: CSIS, February 2025), 43-44, https://www.csis.org/analysis/critical-minerals-and-future-us-economy.

53. "2024 Zinc Futures and Spot Prices Surge Over 18% as Supply-Demand Imbalance Intensifies; Will It Improve in 2025? [Annual Review]," Shanghai Metal Market, January 7, 2025, https://www.metal.com/en/newscontent/103125724.

54. Associated Press, "Montana miner to lay off hundreds due to declining palladium prices," NBC Montana, September 12, 2024, https://nbcmontana.com/news/local/stillwater-mine-lays-off-700-workers.

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