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# The USGS Perspective on Copper as a Critical Mineral

American Copper Council Fall Meeting
November 9, 2023

Steven M. Fortier, PhD
Director, National Minerals Information Center
U.S. Geological Survey

# National Minerals Information Center (NMIC)

- **Mission**
  - **To collect, analyze, and disseminate information on the domestic and international supply of and demand for non-fuel minerals and materials essential to the U.S. economy and national security.**
- **Objective**
  - **Provide decision makers with the information required to ensure that the U.S. has an adequate supply of minerals and materials to meet U.S. needs, at an acceptable cost with regard to environmental, energy, and economic factors.**

# Mineral Information Collection

- More than 140 years of mineral information experience
  - U.S. Geological Survey: 1882-1924
  - U.S. Bureau of Mines: 1925-1995
  - U.S. Geological Survey: 1996 – present

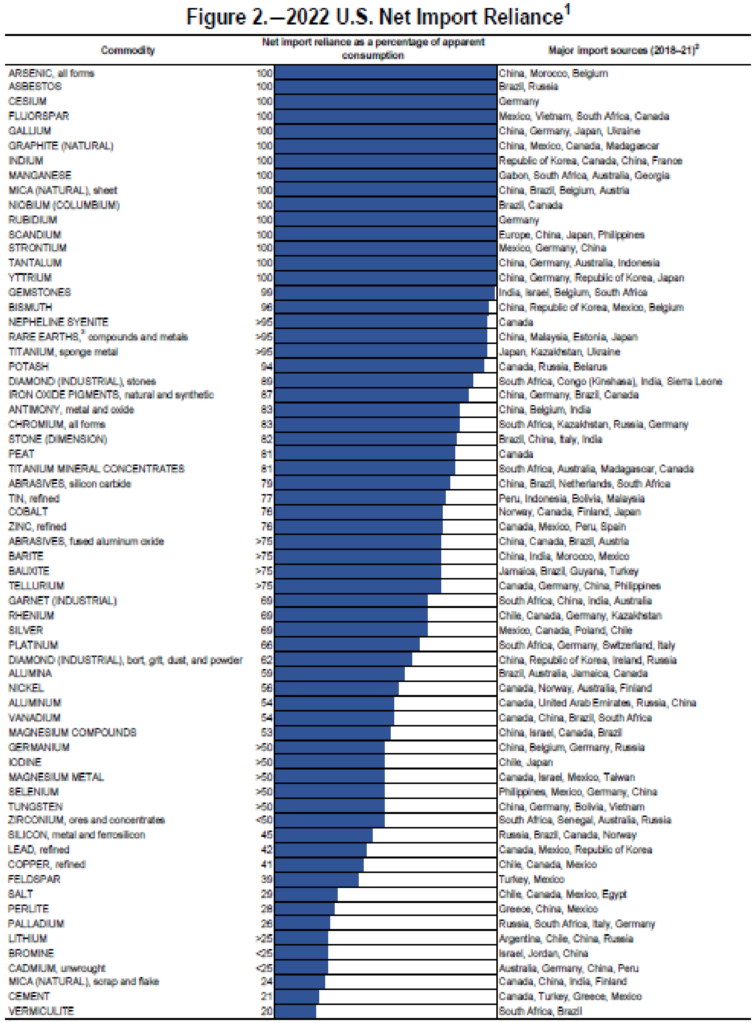
- Domestic mineral information collected on a monthly, quarterly, and annual basis
  - 18,000 mineral related production and consumption establishments
  - 40,000 (voluntary) survey forms completed annually
- Continuous record of mineral commodity supply, consumption, imports, exports, recycling, world production: DS-140

- Global mineral information collection
  - Mineral questionnaires to ~145 countries
  - Site visits
  - Membership on domestic and international mineral related committees
  - Coordination with organizations from other governments and trade associations
  - Reports from economic officers at U.S. embassies
  - Mineral industry reports
  - Company reports

# 2023 Mineral Commodity Summaries

Earliest comprehensive source of domestic and international mineral production data for the prior year.

- Issued annually at the end of January.
- More than 90 individual minerals and materials are covered by 2-page synopses.
- Information on events, trends, and issues for each mineral commodity.
- Production, consumption, trade, stockpile data and analysis.
- U.S. Net Import Reliance.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U.S. Geological Survey, 2023, Mineral commodity summaries 2023: U.S. Geological Survey, 210 p., https://doi.org/10.3133/mcs2023.

# Critical Mineral: Definition

The Energy Act of 2020 defines "critical minerals" as the minerals, elements, substances, or materials that "(i) are essential to the economic or national security of the United States; (ii) the supply chain of which is vulnerable to disruptions (including restrictions associated with foreign political risk, abrupt demand growth, military conflict, violent unrest, anti-competitive or protectionist behaviors, and other risks throughout the supply chain); and (iii) serve an essential function in the manufacturing of a product (including energy technology-, defense-, currency-, agriculture-, consumer electronics-, and healthcare-related applications), the absence of which would have significant consequences for the economic or national security of the United States" (Public Law 116–260, section 7002(c)(4)(A)).

# A risk modeling framework is used to assessing mineral commodities supply chains that pose the greatest risk to the U.S. economy.

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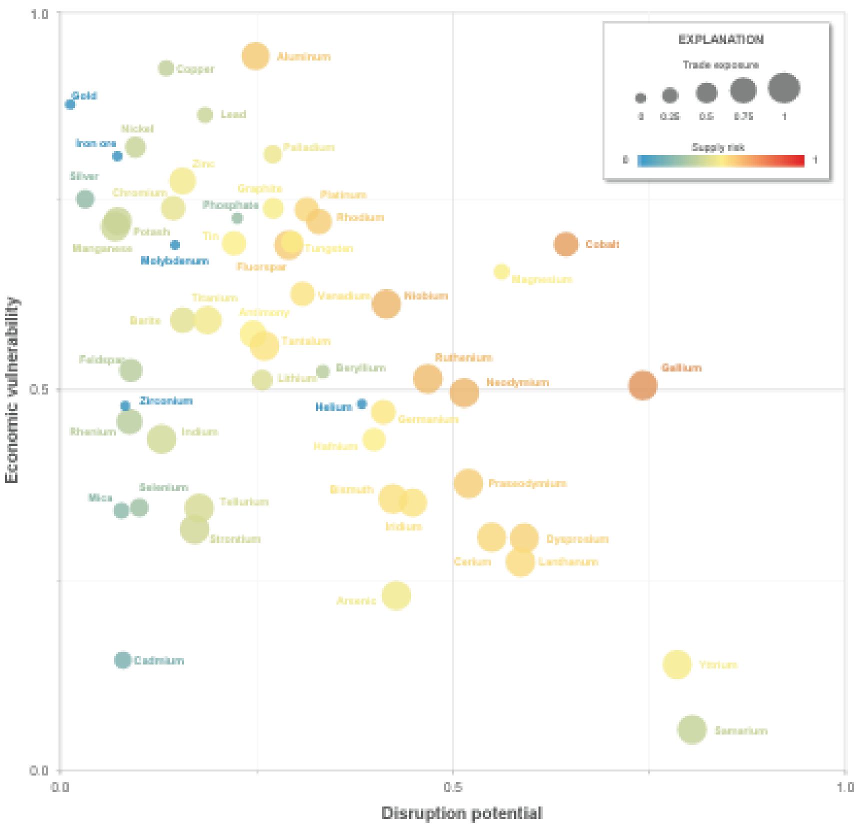
## Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List




| Commodity | Supply risk | | | | | | | | | | | | | Leading producing countries | Byproduct status | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Recency-weighted mean | Names and process stages | Predominately produced as a byproduct | Host commodities |
| Gallium | | | | | | | | | | | | | 0.67 | China | Yes | Bauxite, zinc |
| Niobium | | | | | | | | | | | | | 0.66 | Brazil | No | — |
| Cobalt | | | | | | | | | | | | | 0.65 | DRC (mining), China (refining) | Yes | Copper, nickel |
| Neodymium | | | | | | | | | | | | | 0.65 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Ruthenium | | | | | | | | | | | | | 0.63 | South Africa | Yes | Platinum, nickel |
| Rhodium | | | | | | | | | | | | | 0.62 | South Africa | Yes | Platinum, nickel |
| Dysprosium | | | | | | | | | | | | | 0.61 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Aluminum | | | | | | | | | | | | | 0.60 | China (alumina and aluminum); Australia (bauxite) | No | — |
| Fluorspar | | | | | | | | | | | | | 0.60 | China | No | — |
| Platinum | | | | | | | | | | | | | 0.60 | South Africa | No | — |
| Iridium | | | | | | | | | | | | | 0.59 | South Africa | Yes | Platinum, nickel |
| Praseodymium | | | | | | | | | | | | | 0.58 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Cerium | | | | | | | | | | | | | 0.56 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Lanthanum | | | | | | | | | | | | | 0.56 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Bismuth | | | | | | | | | | | | | 0.55 | China | Yes | Lead, tungsten, copper, tin, molybdenum, fluorspar, zinc |
| Yttrium | | | | | | | | | | | | | 0.54 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Antimony | | | | | | | | | | | | | 0.53 | China | Yes | Lead, gold, other base and precious metals |
| Tantalum | | | | | | | | | | | | | 0.53 | DRC | No | — |
| Hafnium | | | | | | | | | | | | | 0.51 | France | Yes | — |
| Tungsten | | | | | | | | | | | | | 0.51 | China | No | — |
| Vanadium | | | | | | | | | | | | | 0.51 | China | Yes | Steel slag from vanadiferous iron ore, spent catalysts |
| Tin | | | | | | | | | | | | | 0.50 | China (mining and smelting) | No | — |
| Magnesium | | | | | | | | | | | | | 0.49 | China | No | — |
| Germanium | | | | | | | | | | | | | 0.49 | China | Yes | Zinc, coal fly ash |
| Palladium | | | | | | | | | | | | | 0.48 | Russia | Yes | Nickel, platinum |
| Titanium | | | | | | | | | | | | | 0.48 | Australia (mineral concentrate), China (sponge) | No | — |
| Zinc | | | | | | | | | | | | | 0.48 | China (mining and smelting) | No | |
| Graphite | | | | | | | | | | | | | 0.47 | China | | |
| Chromium | | | | | | | | | | | | | 0.47 | South Africa | | |
| Arsenic | | | | | | | | | | | | | 0.45 | China | | |

$$R = H \cdot E \cdot V$$

**Supply Risk**
Risk associated with a supply disruption

**Hazard**
Likelihood of a supply disruption

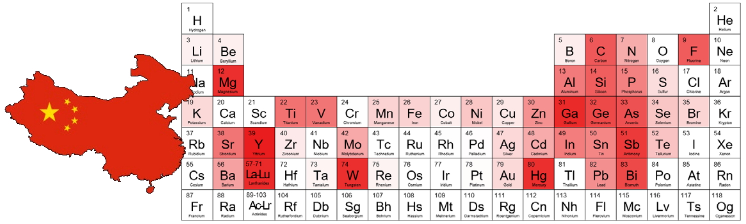
**Exposure**
Degree of exposure to a supply disruption

**Vulnerability**
Ability to withstand the effects of a supply disruption

All components are necessary; each alone is an insufficient condition for risk

Nassar, N.T., and Fortier, S.M., 2021, Methodology and technical input for the 2021 review and revision of the U.S. Critical Minerals List: U.S. Geological Survey Open-File Report 2021–1045, 31 p., https://doi.org/10.3133/ofr20211045.

| | Supply Disruption Potential | Trade Exposure | Economic Vulnerability |
|---|---|---|---|
| **Issue** | Likelihood of a foreign supply disruption | Degree of exposure to a supply disruption | Ability to withstand the effects of a supply disruption |
| **Indicator** | Concentration of production in countries that may become unable or unwilling to supply the United States | Net import reliance as a percentage of apparent consumption | Annual expenditure on the mineral commodity by each industrial sector relative to each sector's profitability |



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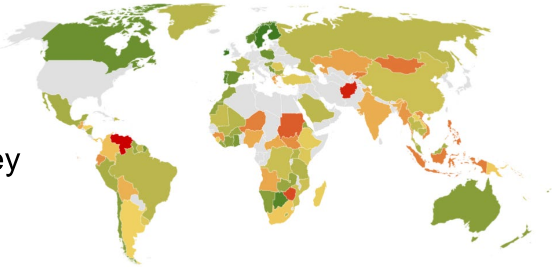
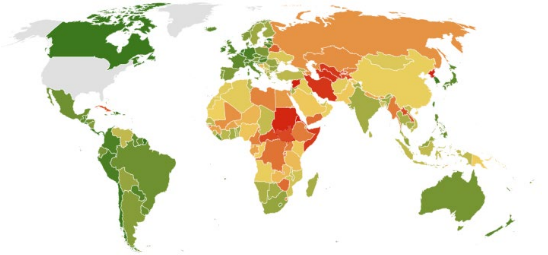
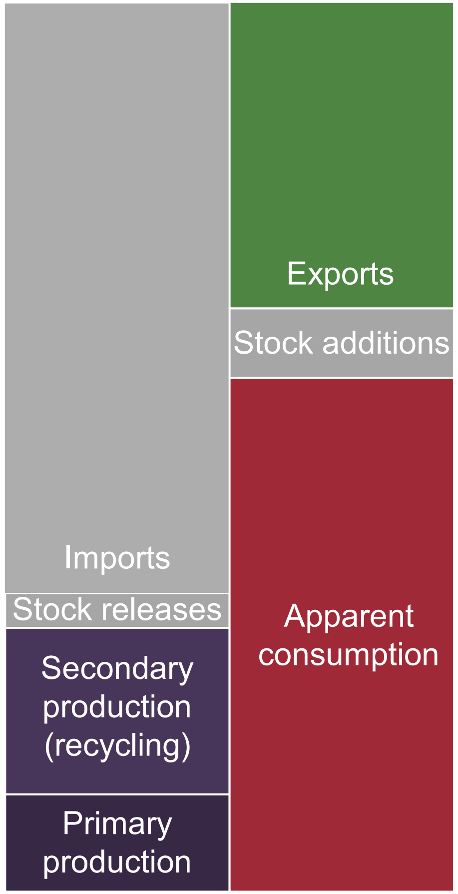
Annual Survey of Mining Companies



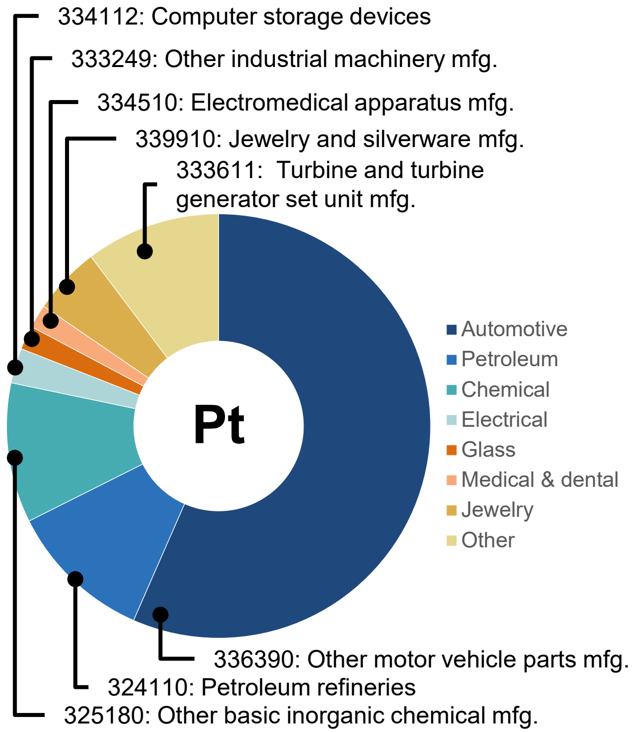
Willingness to Supply Index






United States Census Bureau

ECONOMIC CENSUS

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# A subset of mineral commodities pose the greatest supply risk for the U.S. manufacturing sector.

| | Supply Risk (SR) | | | | | | | | | | | | | Leading producing countries | Byproduct status | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Commodity | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Recency-weighted mean | Names and process stages | Predominately produced as a byproduct | Host commodities |
| Gallium | | | | | | | | | | | | | 0.67 | China | Yes | Bauxite, zinc |
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| Graphite | | | | | | | | | | | | | 0.47 | China | No | — |
| Chromium | | | | | | | | | | | | | 0.47 | South Africa | No | — |
| Arsenic | | | | | | | | | | | | | 0.45 | China | Yes | Copper, gold, lead, zinc |
| Barite | | | | | | | | | | | | | 0.44 | China | No | — |
| Indium | | | | | | | | | | | | | 0.41 | China | Yes | Zinc |
| Samarium | | | | | | | | | | | | | 0.40 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Manganese | | | | | | | | | | | | | 0.40 | South Africa | No | — |
| Lithium | | | | | | | | | | | | | 0.40 | Australia (mining), China (refining) | No | — |
| Tellurium | | | | | | | | | | | | | 0.40 | China | Yes | Copper, lead, nickel, platinum, zinc |

**Supply risk**

Low risk — High risk

Nassar, N.T., and Fortier, S.M., 2021, Methodology and technical input for the 2021 review and revision of the U.S. Critical Minerals List: U.S. Geological Survey Open-File Report 2021–1045, 31 p., https://doi.org/ 10.3133/ ofr20211045.

| Commodity | Supply risk | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| Gallium | | | | | | | | | | | | | 0.67 |
| Niobium | | | | | | | | | | | | | 0.66 |
| Cobalt | | | | | | | | | | | | | 0.65 |
| Neodymium | | | | | | | | | | | | | 0.65 |
| Ruthenium | | | | | | | | | | | | | 0.63 |
| R | | | | | | | | | | | | | |

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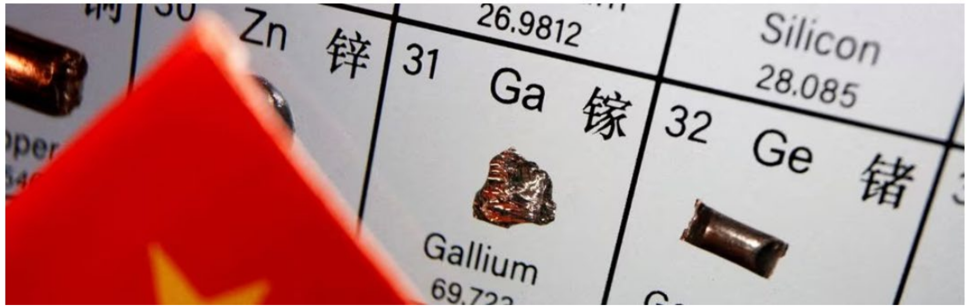
Commodities

# China gallium, germanium export curbs kick in; wait for permits starts

Reuters

August 1, 2023 7:30 AM EDT · Updated an hour ago

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# Gallium and germanium: What China's new move in microchip war means for world

15 hours ago

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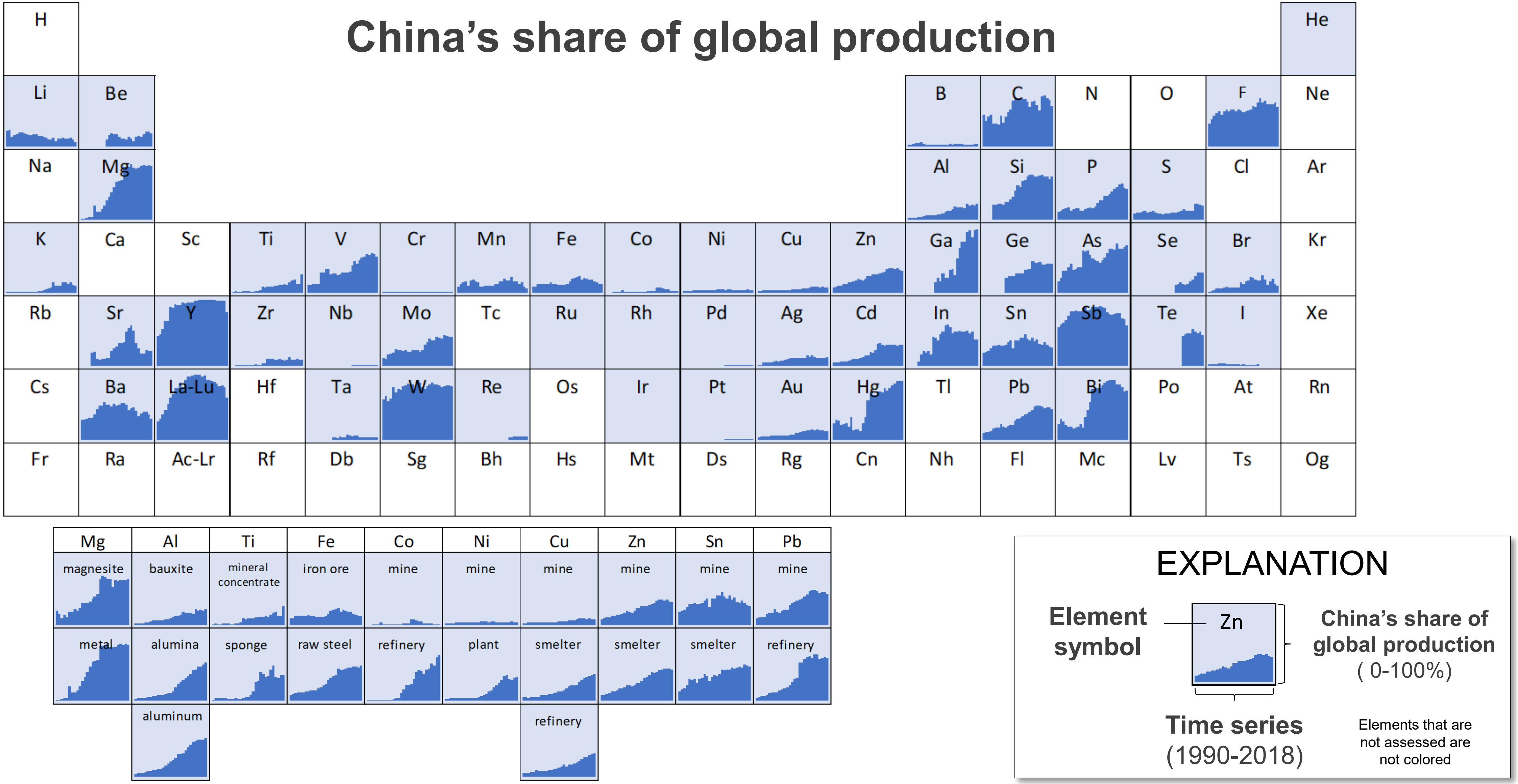
# GALLIUM

(Data in kilograms of contained gallium unless otherwise noted)

| **Salient Statistics—United States:** | **2018** | **2019** | **2020** | **2021** | **2022[e]** |
|---|---|---|---|---|---|
| Production, primary | — | — | — | — | — |
| Imports for consumption: | | | | | |
| Metal | 32,000 | 5,740 | 4,430 | 8,890 | 12,000 |
| Gallium arsenide wafers (gross weight) | 444,000 | 272,000 | 178,000 | 306,000 | 550,000 |
| Exports | NA | NA | NA | NA | NA |
| Consumption, reported | 15,000 | 14,900 | 15,700 | 17,100 | 18,000 |
| Price, average unit value of imports, dollars per kilogram: | | | | | |
| High-purity, refined[1] | 508 | 573 | 596 | 625 | 640 |
| Low-purity, primary[2] | 185 | 153 | 163 | 254 | 420 |
| Stocks, consumer, yearend | 2,920 | 2,850 | 2,920 | 2,810 | 2,800 |
| Net import reliance[3] as a percentage of reported consumption | 100 | 100 | 100 | 100 | 100 |

**Recycling:** Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in New York.

# China's share of global production has increased markedly over the past three decades for many mineral commodities.




Nassar, N.T., Alonso, E., and Brainard, J.L., 2020, Investigation of U.S. Foreign Reliance on Critical Minerals—U.S. Geological Survey Technical Input Document in Response to Executive Order No. 13953 Signed September 30, 2020 (Ver. 1.1, December 7, 2020): U.S. Geological Survey Open-File Report 2020–1127, 37 p., https://doi.org/10.3133/ofr20201127.

| | | | | |
|---|---|---|---|---|
| Germanium | 0.49 | China | Yes | Zinc, coal fly ash |
| Palladium | 0.48 | Russia | Yes | Nickel, platinum |
| Titanium | 0.48 | Australia (mineral concentrate), China (sponge) | No | — |
| Zinc | 0.48 | China (mining and smelting) | No | — |
| Graphite | 0.47 | China | No | — |
| Chromium | 0.47 | South Africa | No | — |
| Arsenic | 0.45 | China | Yes | Copper, gold, lead, zinc |
| Barite | 0.44 | China | No | — |
| Indium | 0.41 | China | Yes | Zinc |
| Samarium | 0.40 | China (mining and refining) | Yes | Iron ore, titanium, zirconium, other rare earths |
| Manganese | 0.40 | South Africa | No | — |
| Lithium | 0.40 | Australia (mining), China (refining) | No | — |
| Tellurium | 0.40 | China | Yes | Copper, lead, nickel, platinum, zinc |
| Lead | 0.39 | China (mining and refining) | No | — |
| Potash | 0.38 | Canada | No | — |
| Strontium | 0.36 | China | No | — |
| Rhenium | 0.36 | Chile | Yes | Molybdenum, copper |
| Nickel | 0.36 | Indonesia (mining), China (refining) | No | — |
| Copper | 0.34 | Chile (mining), China (smelting and refining) | No | — |
| Beryllium | 0.33 | United States | No | — |
| Feldspar | 0.32 | Turkey | No | — |
| Phosphate | 0.25 | China | No | — |
| Silver | 0.25 | Mexico | Yes | Zinc, lead, copper, gold |
| Mica | 0.22 | China | No | — |
| Selenium | 0.23 | Japan | Yes | Copper, lead, nickel, platinum, zinc |

Supply risk

Low risk — High risk

Nassar, N.T., and Fortier, S.M., 2021, Methodology and technical input for the 2021 review and revision of the U.S. Critical Minerals List: U.S. Geological Survey Open-File Report 2021–1045, 31 p., https://doi.org/10.3133/ofr20211045

**Table 1.** Threshold criteria for each supply risk component.

[ASI, ability to supply index; WSI, willingness to supply index]

| | Supply risk component | | |
|---|---|---|---|
| | **Disruption potential** | **Trade exposure** | **Economic vulnerability** |
| Threshold criteria description | Global production of the commodity outside the United States was concentrated such that one-half was from a single country that was less able or less willing to continue to supply to the United States than the average country (specifically defined as the 75th percentile ASI and WSI indicators), or an equivalent production distribution that resulted in the same normalized score. | One-half of U.S. consumption of the commodity was obtained from foreign sources. | Annual expenditures on the commodity were equal to the median commodity expenditure (across all commodities and years evaluated) in a manufacturing industry that had a below average (75th percentile) operating profits-to-value-added ratio, or equivalent normalized score. |
| Normalized score corresponding to threshold criteria (0–1 scale) | 0.20 | 0.50 | 0.64 |



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# COPPER

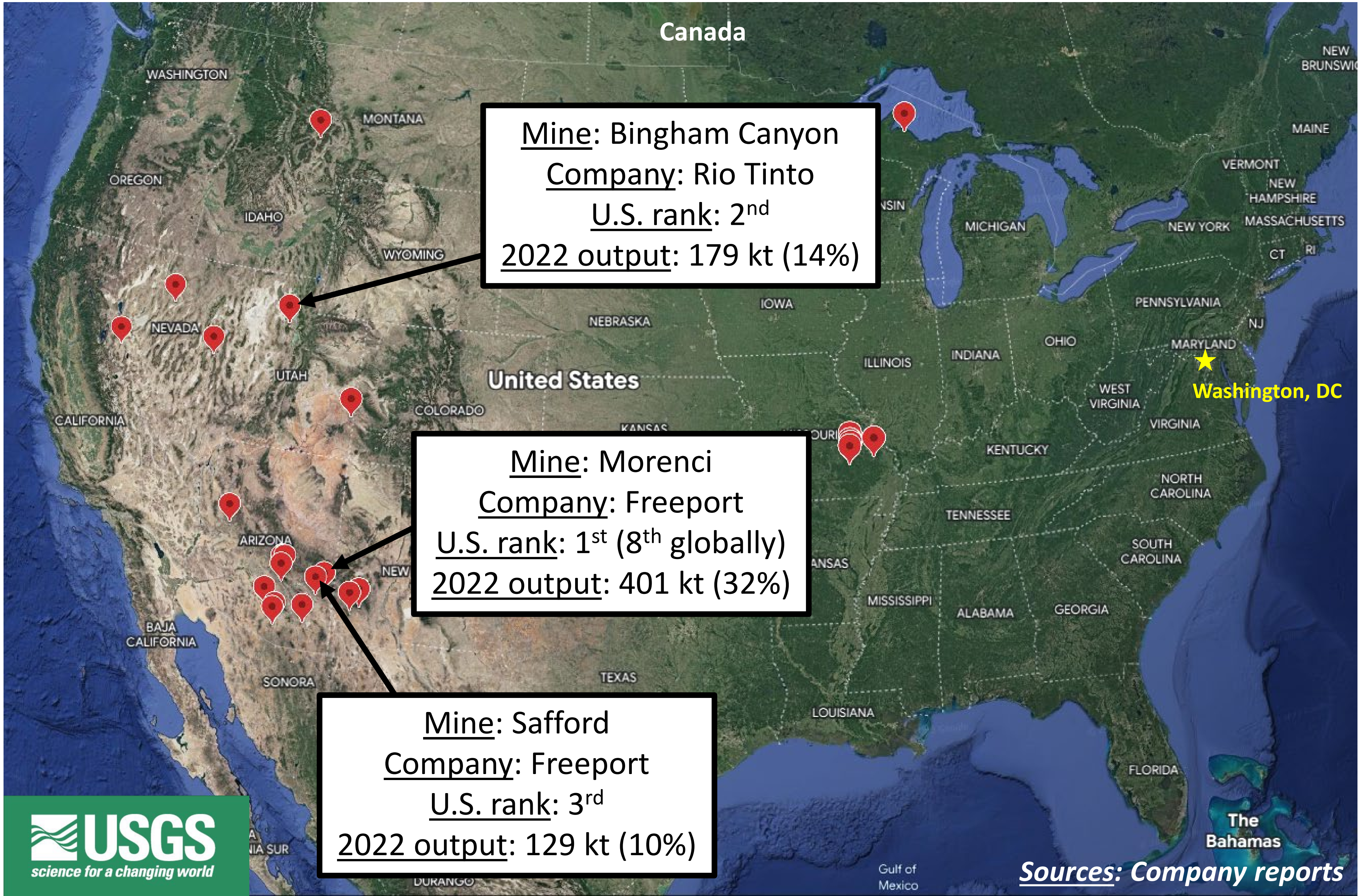
(Data in thousand metric tons of contained copper unless otherwise noted)

| **Salient Statistics—United States:** | **2018** | **2019** | **2020** | **2021** | **2022[e]** |
|---|---|---|---|---|---|
| Production: | | | | | |
| Mine, recoverable copper content | 1,220 | 1,260 | 1,200 | 1,230 | 1,300 |
| Refinery: | | | | | |
| Primary (from ore) | 1,070 | 985 | 874 | 922 | 960 |
| Secondary (from scrap) | 41 | 44 | 43 | 49 | 40 |
| Copper recovered from old (post-consumer) scrap[2] | 141 | 166 | 160 | [e]170 | 160 |
| Imports for consumption: | | | | | |
| Ore and concentrates | 32 | 27 | 2 | 11 | 15 |
| Refined | 778 | 663 | 676 | 919 | 810 |
| Exports: | | | | | |
| Ore and concentrates | 253 | 356 | 383 | 347 | 330 |
| Refined | 190 | 125 | 41 | 48 | 30 |
| Consumption: | | | | | |
| Reported, refined metal | 1,820 | 1,810 | 1,770 | 1,770 | 1,800 |
| Apparent, primary refined and old scrap[3] | 1,820 | 1,820 | 1,660 | 1,960 | 1,900 |
| Price, annual average, cents per pound: | | | | | |
| U.S. producer, cathode (COMEX + premium) | 298.7 | 279.6 | 286.7 | 432.3 | 410 |
| COMEX, high-grade, first position | 292.6 | 272.3 | 279.9 | 424.3 | 400 |
| London Metal Exchange, grade A, cash | 296.0 | 272.4 | 279.8 | 422.5 | 400 |
| Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend | 244 | 110 | 118 | 117 | 120 |
| Employment, mine and plant, number | 11,700 | 12,000 | 11,000 | 11,400 | 12,000 |
| Net import reliance[4] as a percentage of apparent consumption | 33 | 37 | 38 | 44 | 41 |

# Copper-Producing Mines in the United States


***Sources*: Various, public domain**

# Leading U.S. Copper Producing Mines



# U.S. Refined Copper Production

- Total output in 2022 = 952 kt
  - 555 kt copper via SX-EW (58%)
  - 357 kt primary electrolytic copper (38%)
  - 40 kt secondary fire-refined copper (4%)
- Leading companies in 2022:
  - Freeport-McMoRan — 671 kt (70%) — 8 ops. (7 electrowon, 1 electrolytic)
  - Rio Tinto — 148 kt (16%) — 1 op. (electrolytic)
- 8 other companies account for the remaining 14% of production

***Sources**: USGS data and company reports*

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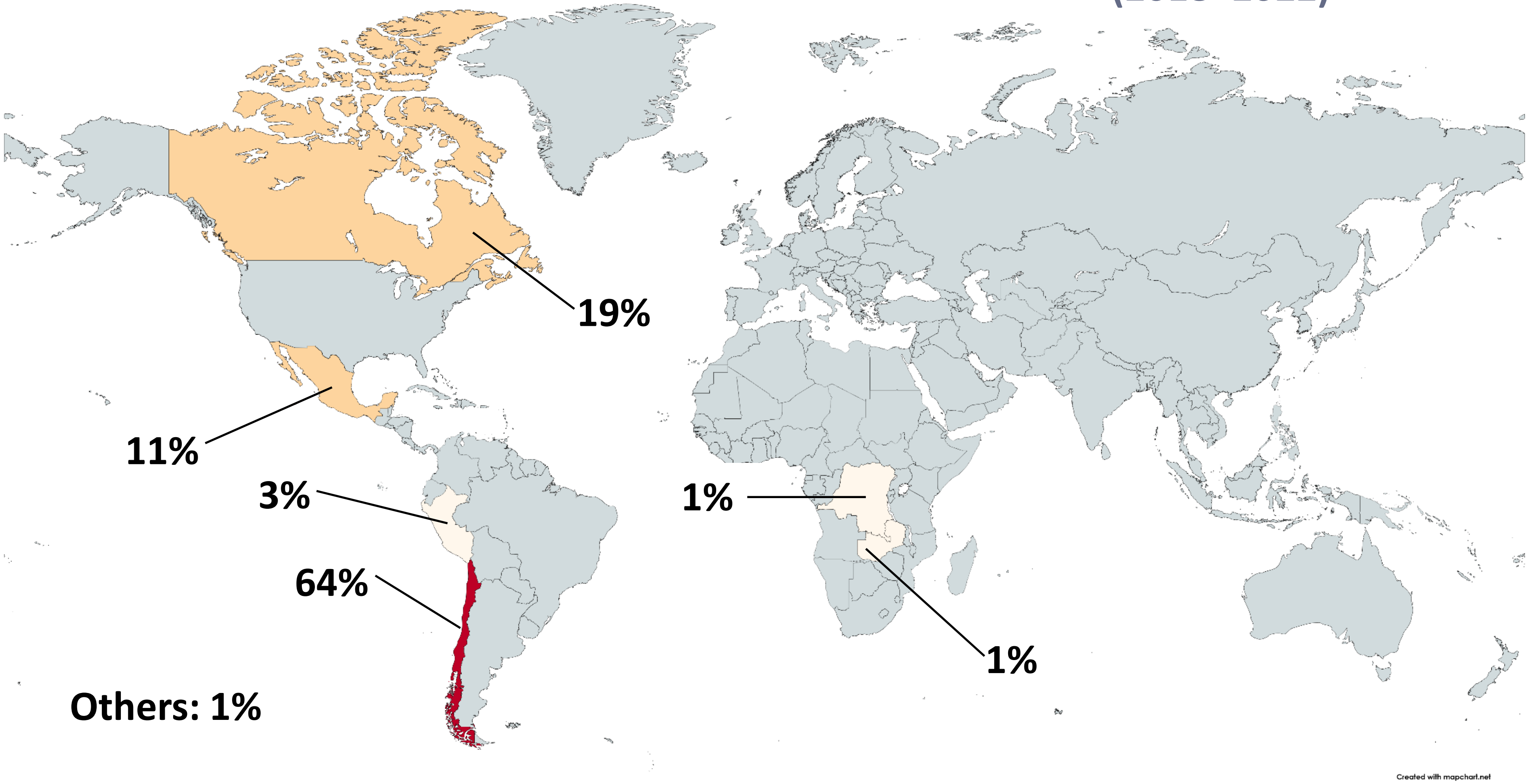
# Import Sources of Refined Copper

(2018–2022)




Imports in 2022 = 732 kt
(43% of reported refined usage)

The United States is a significant global importer of refined copper — by quantity, only China imports more.

*__Source__: U.S. Census Bureau*

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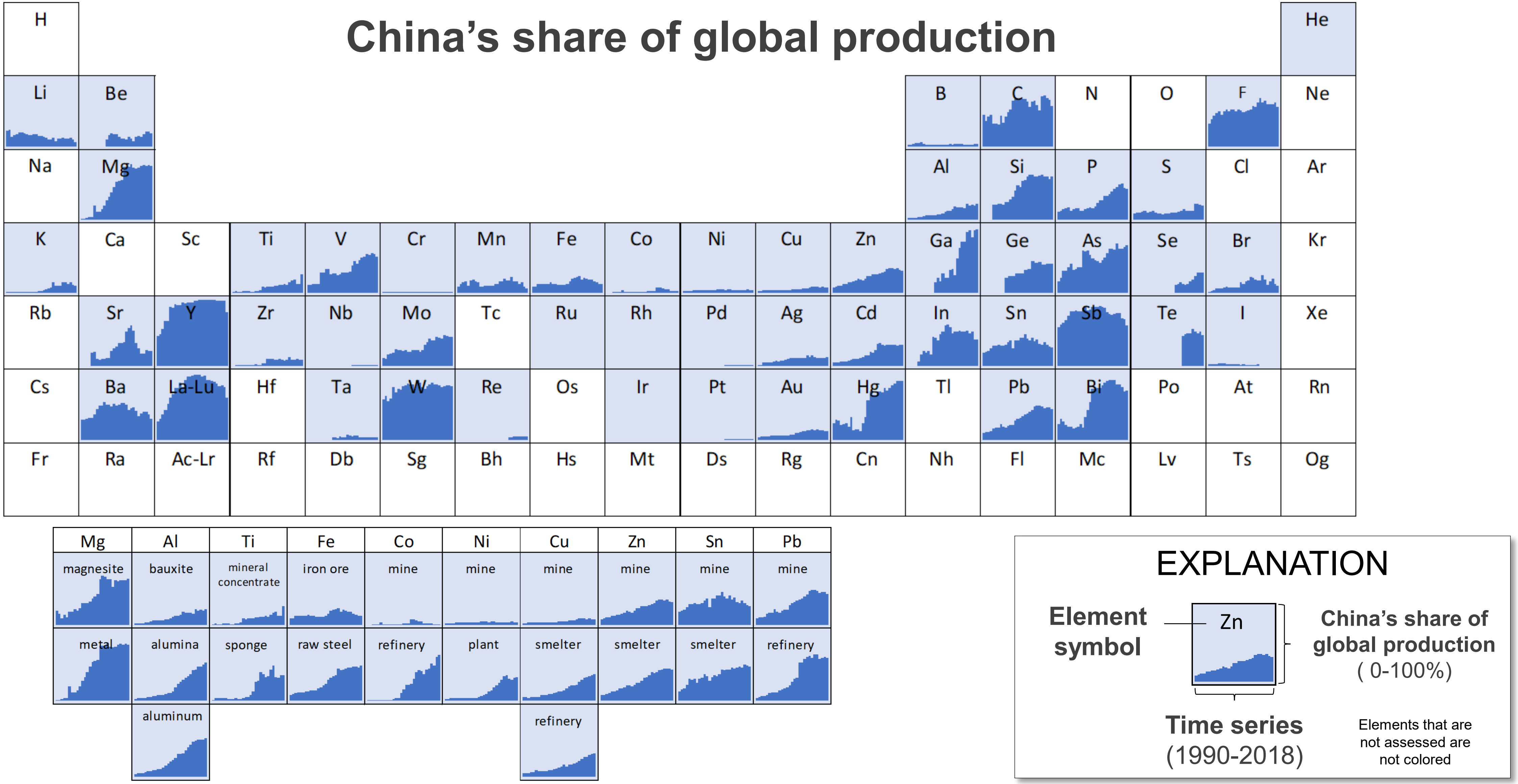
# China’s share of global production has increased markedly over the past three decades for many mineral commodities.

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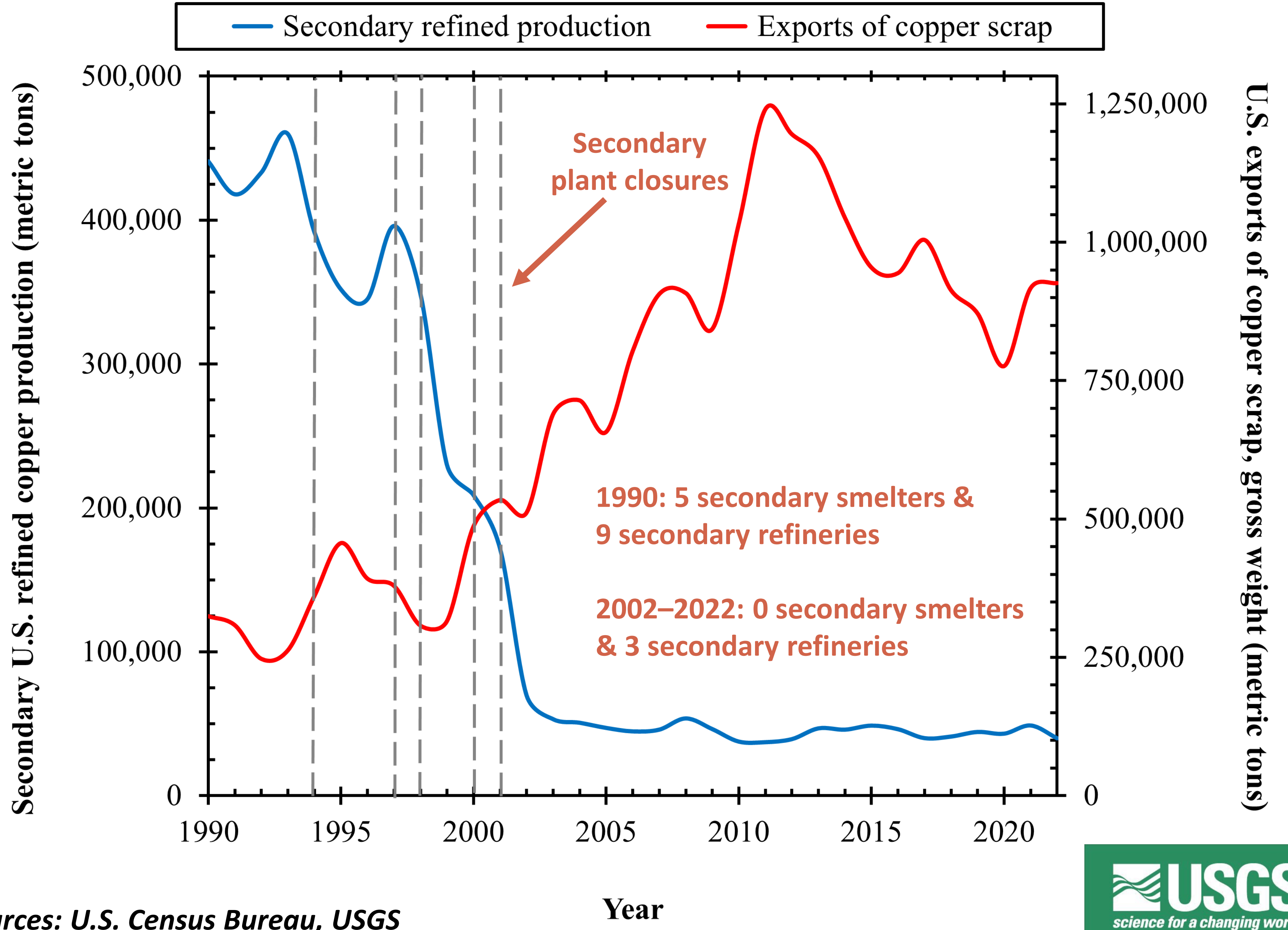
# The Decline of U.S. Processing of Copper Scrap




***Sources: U.S. Census Bureau, USGS***

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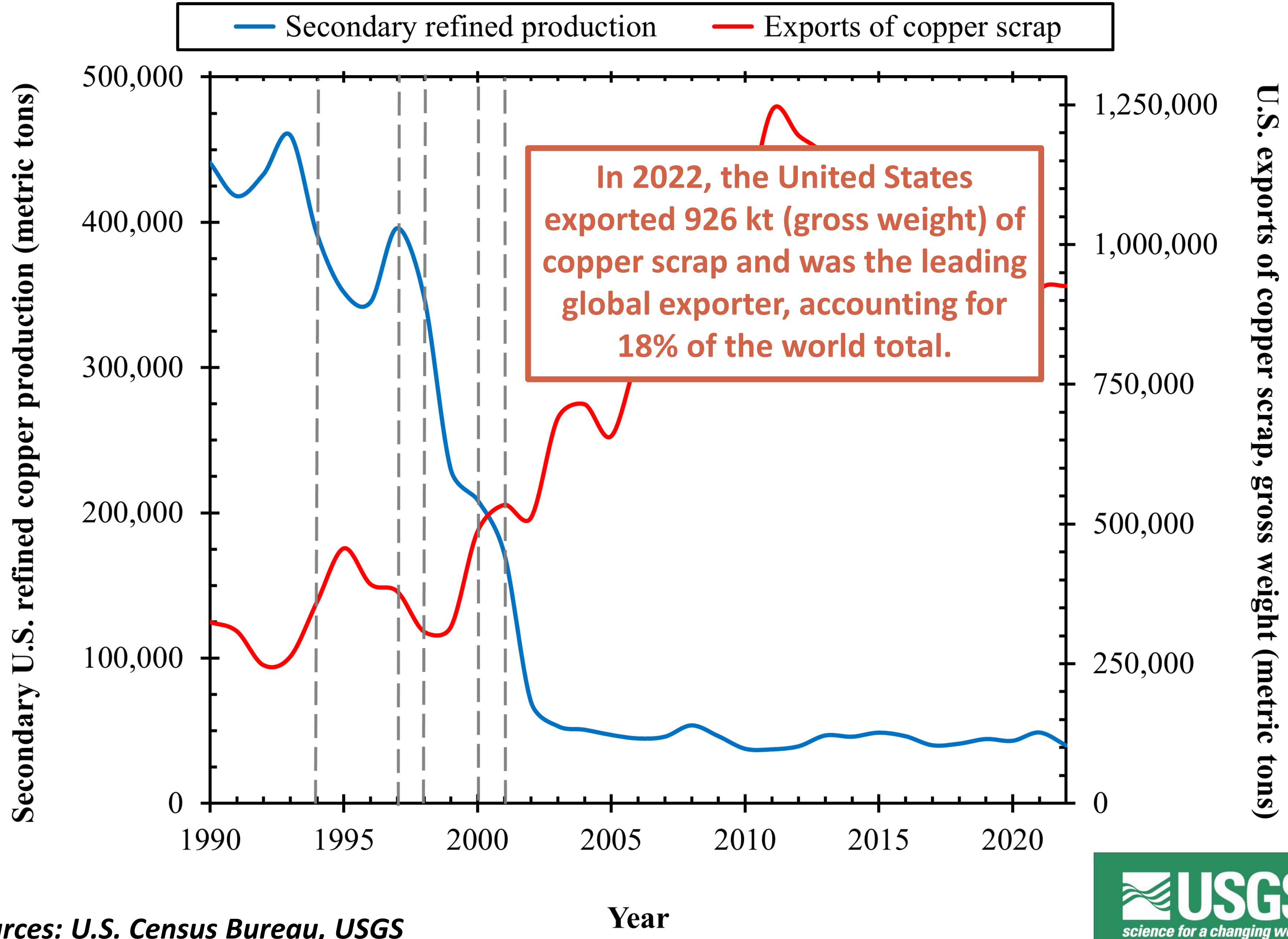


***Sources*: U.S. Census Bureau, USGS**

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# Department of Energy Critical Materials Assessment

| | | | |
|---|---|---|---|
| Potash | 0.38 Canada | No | — |
| Strontium | 0.36 China | No | — |
| Rhenium | 0.36 Chile | Yes | Molybdenum, copper |
| Nickel | 0.36 Indonesia (mining), China (refining) | No | — |
| Copper | 0.34 Chile (mining), China (smelting and refining) | No | — |
| Beryllium | 0.33 United States | No | — |
| Feldspar | 0.32 Turkey | No | — |
| Phosphate | | | |
| Silver | | | |
| Mica | | | |

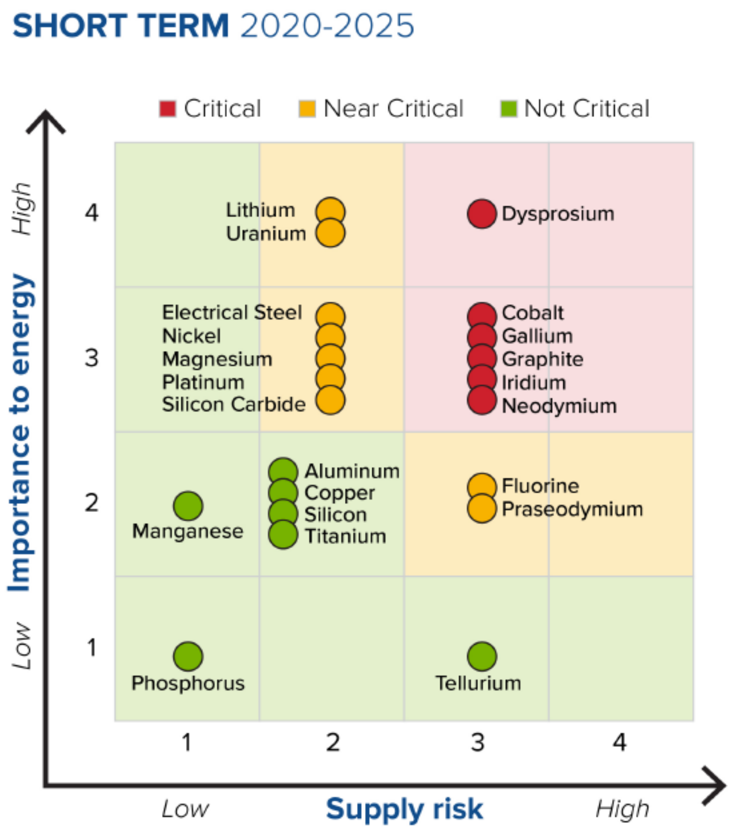



Figure 3.1 Short-term (2020–2025) criticality matrix

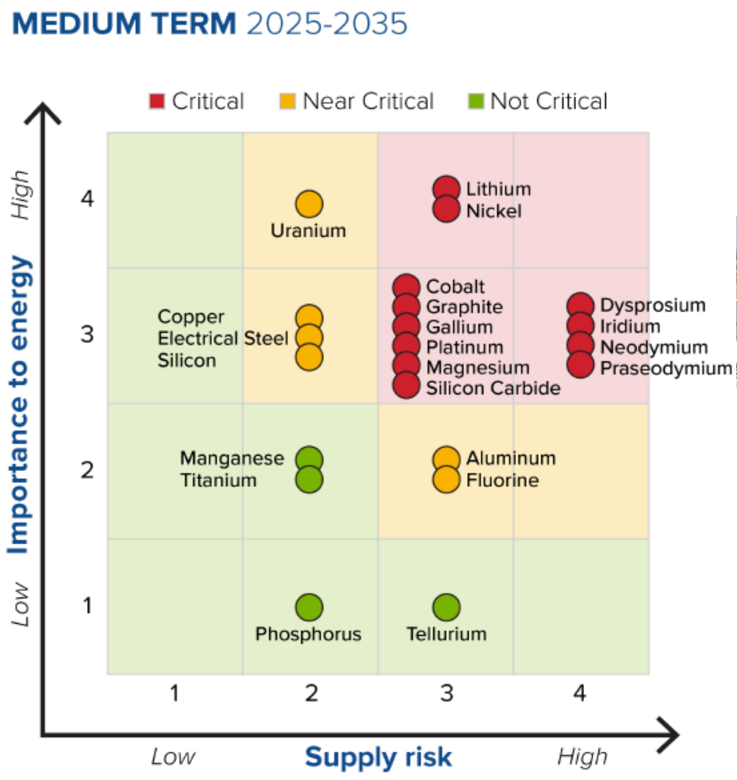



Figure 3.2 Medium-term (2025–2035) criticality matrix

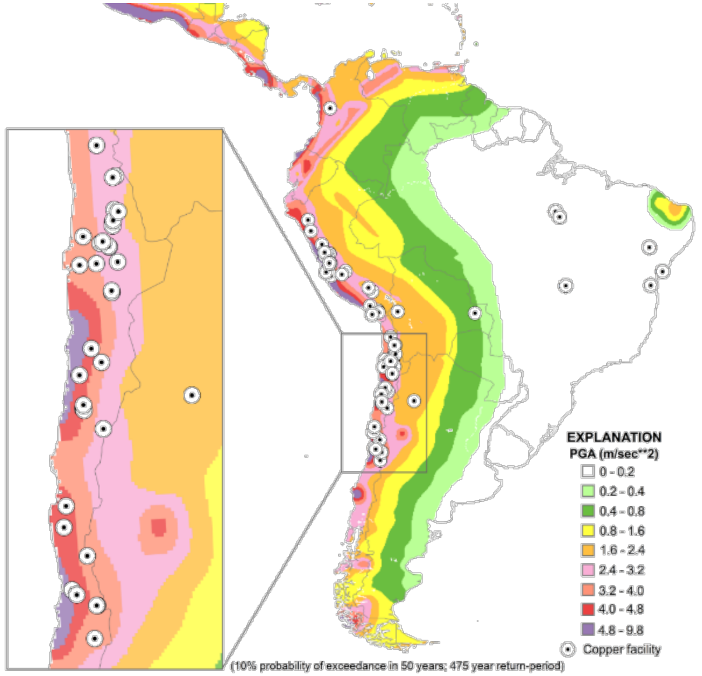

USGS science for a changing world

https://www.energy.gov/sites/default/files/2023-05/2023-critical-materials-assessment.pdf

# Ongoing work seeks to improve and expand each of the components of supply risk.

## Disruption Potential

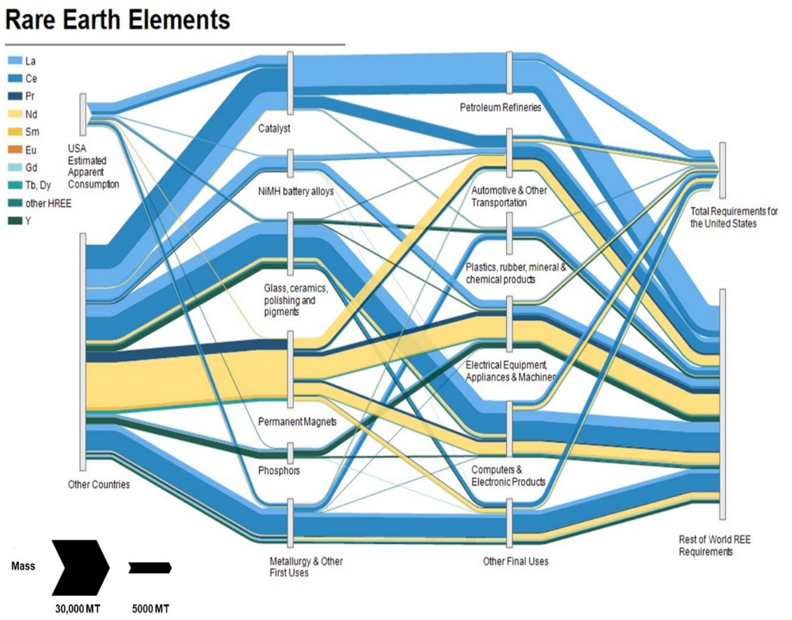
Accounting of other hazards, such as natural hazards, impacts of climate change, and developing supply disruptions scenarios




Schnebele, E.; Jaiswal, K.; Luco, N.; Nassar, N. T. Natural Hazards and Mineral Commodity Supply: Quantifying Risk of Earthquake Disruption to South American Copper Supply. *Resources Policy* 2019, *63*, 101430.

## Trade Exposure

Incorporating indirect trade, materials embedded in finished goods, and ownership of foreign mineral assets

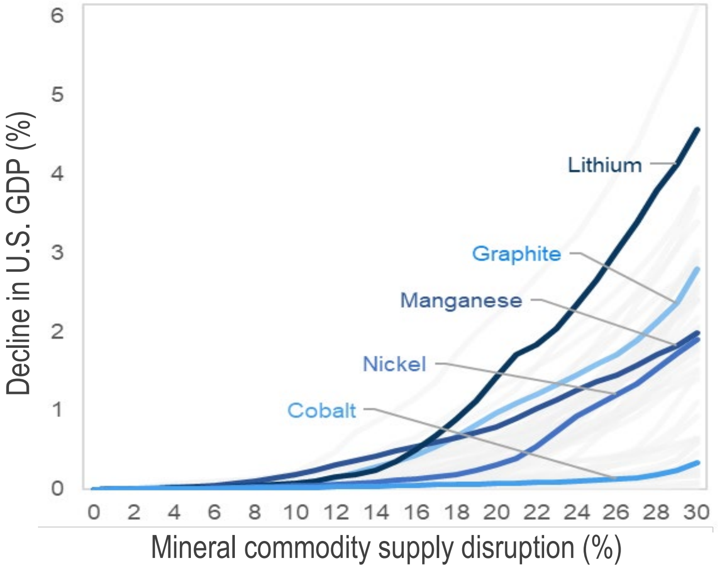



Alonso, E., Pineault, D.G., Gambogi, J., and Nassar, N.T., 2023, Mapping first to final uses for rare earth elements, globally and in the United States: Journal of Industrial Ecology, v. 27, no. 1, p. 312–322.

## Economic Vulnerability

Integrating economic input-output tables to quantify how disruptions might ripple through and impact downstream industries.

Economic impact of mineral commodity supply disruption




Manley, R.L., Alonso, E., and Nassar, N.T., 2022, A model to assess industry vulnerability to disruptions in mineral commodity supplies: Resources Policy, v. 78, p. 102889.

# Increasing Transparency in Critical Materials Price, Supply, and Demand Forecasts

*DARPA OPEN program seeks technology solutions to enhance supply chain resilience, national security by increasing global critical materials market transparency*

OUTREACH@DARPA.MIL
10/25/2023

*OPEN seeks to enhance supply chain resilience, national security by increasing global critical materials market transparency*

In partnership with the United States Geological Survey (USGS), the DARPA Open Price Exploration for National Security (OPEN) program aims to enhance supply chain resilience and national security by spurring the development of technology to increase transparency in critical commodity pricing and supply, demand, and capacity forecasting.

OPEN seeks to analyze commercially and publicly available information on fundamental and observable input costs to construct transparent structural price predictions, and to use advances in time series forecasting, economic modeling, and machine learning to create accurate and precise supply and demand forecasts.

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