

Appendices for

Methodology and Technical Input for the 2025 U.S. List of Critical Minerals—Assessing the Potential Effects of Mineral Commodity Supply Chain Disruptions on the U.S. Economy

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- Appendix 1. World production and production capacity data
- Appendix 2. U.S. trade data of mineral commodities
- Appendix 3. Prices and price elasticities of supply and demand
- Appendix 4. Mineral commodity consumption by application and associated industry
- Appendix 5. Python implementation of economic impacts model
- Appendix 6. Natural breaks classification

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Appendix 1. World production and production capacity data

Data sources, assumptions, and other information for world primary and second production and production capacity are provided in the following tables for each mineral commodity analyzed. Because of the complexity of their production data, rare earth elements are addressed separately at the end of this appendix. Additionally, the industries, as defined in the input-output tables of the Bureau of Economic Analysis (BEA), associated with each production stage are identified (if applicable).

Table A1.1. World primary and secondary production data sources.

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Alumina	Refinery production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Alumina refining and primary aluminum production [331313]	Quantities were converted to aluminum content based on the standard stoichiometric ratio (~52.9%).	Not applicable	Not applicable	Not applicable	Not applicable
Aluminum	Smelter production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Alumina refining and primary aluminum production [331313]	Quantities were reported in aluminum content by the reference.	Secondary aluminum production, old scrap only	(U.S. Geological Survey, 2025a; World Bureau of Metal Statistics, 2022)	Secondary smelting and alloying of aluminum [331314]	U.S. secondary production data were obtained from the Mineral Commodity Summaries (U.S. Geological Survey, 2025a). Data for all other countries were obtained from the World Bureau of Metal Statistics (2022), which pertain to year 2021 but were assumed to be similar in 2023.

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Antimony	Refinery production of metal (sellable ingot) and antimony trioxide	(Project Blue, 2024a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in antimony content by the reference.	Not applicable	Not applicable	Not applicable	Although antimonial lead was recovered from spent lead-acid batteries, this secondary source was largely performed in a closed-loop fashion (Project Blue, 2024a) and was thus excluded from the analysis. Antimony oxide may also have been recovered at the end-of-life, but those quantities were estimated to be relatively small and thus assumed to be negligible (Project Blue, 2024a).
Arsenic	Arsenic compound production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities, which were reported in arsenic trioxide equivalent, were converted into arsenic content based on the standard stoichiometric ratio (75.7%).	Not applicable	Not applicable	Not applicable	Not applicable
Barite	Mine production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were converted to barium content (58.8%).	Not applicable	Not applicable	Not applicable	Not applicable
Bauxite	Mine production	(U.S. Geological Survey,	Iron, gold, silver, and other metal ore	Quantities were converted to aluminum content	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
		2025a; U.S. Geological Survey, 2025b)	mining [2122A0]	<p>based on Al₂O₃ content of bauxite ore grades reported in (Liu and Müller, 2013) and the standard stoichiometric ratio (~52.9%). For countries not included by the reference, the Al₂O₃ content of bauxite was assumed to be 41%.</p> <p>U.S. production was withheld by the reference to avoid disclosing proprietary information but was included in the analysis.</p>				
Beryllium	Mine production	(U.S. Geological Survey, 2025a)	Other nonmetallic mineral mining and quarrying [2123A0]	<p>In addition to the countries listed by the reference, Kazakhstan was believed to have produced beryllium metallurgical products from stockpiles of concentrates (Beryllium Science & Technology Association, 2024). Kazakhstan production was thus estimated assuming its beryllium metallurgical product</p>	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
				production (U.S. Geological Survey, 2025b) was 4% beryllium content. Production from all other countries was reported in beryllium content.				
Bismuth	Refinery production	(U.S. Geological Survey, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in bismuth content by the reference.	Not applicable	Not applicable	Not applicable	The minor quantities (approximately 40 metric tons) of bismuth that were recycled were thought to be new scrap and thus excluded from the analysis (U.S. Geological Survey, 2025a).
Cadmium	Refinery production	(U.S. Geological Survey, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in cadmium content by the reference.	Not applicable	Not applicable	Not applicable	Although cadmium was recovered from spent consumer and industrial batteries and other sources, no reliable country-level information was available, except for the United States which was included in the analysis.
Chromite	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were converted to chromium content based on values reported by Nassar and others (2020).	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Chromium chemicals	Production of chromium chemicals	(Project Blue, 2025a)	Other basic inorganic chemical manufacturing [325180]	Quantities were converted from sodium dichromate equivalent to chromium content (~34.9%).	Not applicable	Not applicable	Not applicable	Not applicable
Chromium ferroalloys	Ferrochromium production (high-, medium- and low-carbon alloys)	(Project Blue, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in chromium content by the reference.	Not applicable	Not applicable	Not applicable	Chromium is mainly recycled in the form of stainless-steel scrap, which was excluded from this analysis.
Chromium metal	Production of chromium metals	(Project Blue, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in chromium content by the reference.	Not applicable	Not applicable	Not applicable	No reliable estimates of chromium metal recycled by country were available.
Cobalt chemicals	Refinery production of cobalt chemicals and fine powders	(Darton Commodities Limited, 2025)	Other basic inorganic chemical manufacturing [325180]	Quantities were reported in cobalt content by the reference.	Not applicable	Not applicable	Not applicable	Not applicable
Cobalt metal	Refinery production cobalt metal and coarse powder	(Darton Commodities Limited, 2025)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in cobalt content by the reference.	Secondary production	(Darton Commodities Limited, 2025; U.S. Geological Survey, 2025a)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	U.S. secondary production of cobalt was obtained from the U.S. Geological Survey (2025a). The rest of world's secondary production was estimated based on the difference between the total secondary cobalt production obtained

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
								from Darton Commodities Limited (2025) and the quantity of U.S. secondary cobalt production. Due to lack of better information, this remaining quantity was allocated to several countries (Belgium, Canada, China, Finland, France, Japan, Norway, South Korea, and the United Kingdom) based on their reported cobalt refinery capacity.
Copper, mined	Mine production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Copper, nickel, lead, and zinc mining [212230]	Quantities were reported in copper content by the reference.	Not applicable	Not applicable	Not applicable	Not applicable
Copper, refined	Primary refinery production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in copper content by the reference.	Secondary refinery production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Copper Rolling, Drawing, Extruding, and Alloying [331420]	Quantities were reported in copper content by the reference. For the United States, secondary production was set equal to the quantity of copper recovered from old (post-consumer) scrap.

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Feldspar	Feldspar mine production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were not adjusted for any elemental content. Nepheline syenite mine production was excluded if readily identifiable in the reported data.	Not available	Not applicable	Not applicable	Not applicable
Fluorspar, acidspar	Acid-grade fluorspar (acidspar) production	(Project Blue, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were assumed to be 47.7% fluorine content.	Not available	Not applicable	Not applicable	Not applicable
Fluorspar, metspar	Metallurgical-grade fluorspar (metspar) production	(Project Blue, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were assumed to be 45.7% fluorine content.	Not available	Not applicable	Not applicable	Not applicable
Gallium	Low-purity refinery production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in gallium content by the reference.	Not applicable	Not applicable	Not applicable	End-of-life recycling was assumed to be negligible. New scrap recycling was excluded from the analysis.
Germanium	Refinery production	(Nassar and others, 2024)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were updated to reflect production quantities in 2023 based on the same sources and methods used by the reference. Quantities were reported in germanium content by the reference.	Not applicable	Not applicable	Not applicable	End-of-life recycling was assumed to be negligible. New scrap recycling was excluded from the analysis.

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Gold	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in gold content by the reference.	Old scrap gold recycling	(World Gold Council, 2024)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities, which were only reported by the reference as a total for the world, were disaggregated by country assuming the same relative contribution of each country as reported by Alexander and others (2019) for year 2018. Quantities were reported in gold content by the reference.
Graphite, natural	Natural graphite production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	All quantities were assumed to be reported in graphite content.	Not applicable	Not applicable	Not applicable	Not applicable
Graphite, synthetic	Synthetic graphite production	(Benchmark Mineral Intelligence Ltd., 2023)	Other petroleum and coal products manufacturing [324190]	All quantities were assumed to be reported in graphite content.	Not applicable	Not applicable	Not applicable	Not applicable
Hafnium	Refinery production	(Mordor Intelligence, 2024)	Nonferrous metal (except aluminum) smelting and refining [331410]	All quantities were reported in hafnium content.	Not applicable	Not applicable	Not applicable	Not applicable
Helium	Grade-A and gaseous helium	(U.S. Geological Survey, 2025a)	Industrial gas manufacturing [325120]	Quantities were assumed to be reported in helium content. U.S. quantities included those extracted from	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
				natural gas, as well as those withdrawn from storage				
Indium	Refinery production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in indium content by the reference.	Not applicable	Not applicable	Not applicable	Although there were notable quantities of new scrap recycling of indium (especially of indium-tin-oxide), end-of-life recycling of indium was assumed to be negligible.
Iridium	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in iridium content by the reference. Additionally, U.S. mine production was estimated separately based on palladium mine production multiplied by the iridium-to-palladium ratio reported by Naldrett (2011).	End-of-life recycling	Refer to comment	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Closed-loop recycling of iridium from industrial applications (chemical catalysts and electrochemical applications) was excluded. Non-closed loop end-of-life recycling were estimated using the method described by Nassar (2015) and data from Johnson Matthey Plc (2024). The quantity that was estimated to be recycled at the end-of-life were allocated to individual countries based on the same proportions as platinum recycling.
Iron ore	Mine production, as well as alternative iron	(U.S. Geological	Iron, gold, silver, and other metal ore	Quantities were reported in iron	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
	ore sources including nickeliferous iron ore and titaniferous magnetite beach sands	Survey, 2025b)	mining [2122A0]	content by the reference.				
Lead	Primary refined production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in lead content by the reference.	Secondary refined production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities were reported in lead content by the reference.
Lithium	Refined lithium production	(Project Blue, 2025c)	Other basic inorganic chemical manufacturing [325180]	Quantities were converted from lithium-carbonate equivalent to lithium content based on standard stoichiometric ratio (18.8%)	Not available	Not applicable	Not applicable	The minor quantities of lithium recycled at the end-of-life (Project Blue, 2025c) were excluded due to lack of country-level data.
Magnesium compounds	Magnesite and seawater and brine production	(U.S. Geological Survey, 2025b)	Other basic inorganic chemical manufacturing [325180]	Quantities, which were reported in MgO equivalent, were converted to magnesium content using the standard stoichiometric ratio (60.35%). Magnesium compounds from seawater and brines were estimated from production capacity quantities, as reported by the reference,	Not available	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
				multiplied by an assumed 80% capacity utilization rate.				
Magnesium metal	Primary production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in magnesium content by the reference.	Secondary production	(Project Blue, 2025d; U.S. Geological Survey, 2025b)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Secondary magnesium production for the United States was based on quantity recovered from old scrap only as reported by the U.S. Geological Survey (2025b). Secondary production for all other countries obtained from Project Blue (Project Blue, 2025d)
Manganese alloys	Refinery production of high-carbon ferromanganese, medium- and low-carbon ferromanganese, and silicomanganese	(Project Blue, 2025e)	Iron and steel mills and ferroalloy manufacturing [331110]	Quantities were reported in manganese content by the reference.	Not available	Not applicable	Not applicable	Not applicable
Manganese dioxide	Refinery production	(Project Blue, 2024b)	Other basic inorganic chemical manufacturing [325180]	Quantities were reported in manganese content by the reference.	Not available	Not applicable	Not applicable	Not applicable
Manganese metal	Electrolytic or aluminothermic manganese metal production	(Project Blue, 2025e)	Iron and steel mills and ferroalloy manufacturing [331110]	Quantities were reported in manganese content by the reference.	Not available	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Manganese ore	Mine production	(International Manganese Institute, 2024)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were reported in manganese content by the reference.	Not available	Not applicable	Not applicable	Not applicable
Manganese sulfate (high purity)	Refinery production of battery-grade manganese sulfate	(Project Blue, 2025e)	Other basic inorganic chemical manufacturing [325180]	Quantities were reported in manganese content by the reference.	Not available	Not applicable	Not applicable	Not applicable
Mica	Mine (scrap and flake) production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were not adjusted for any elemental content. Production excludes sheet mica where it is distinguishable in the data.	Not available	Not applicable	Not applicable	Not applicable
Molybdenum	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in molybdenum content by the reference.	Not available	Not applicable	Not applicable	Molybdenum is recycled in notable quantities in the form of spent catalysts, ferrous scrap, and superalloy revert. No recent production quantities were available, and thus secondary production was excluded from the analysis.
Nickel, mined	Mine production	(U.S. Geological Survey, 2025b)	Copper, nickel, lead, and zinc mining [212230]	Quantities were reported in nickel content by the reference.	Not available	Not applicable	Not applicable	Not applicable
Nickel, primary refined	Primary refinery production	(U.S. Geological	Nonferrous metal (except aluminum)	Quantities were reported in nickel	Not available	Not applicable	Not applicable	Nickel is extensively recycled, especially in the form of stainless-

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
		Survey, 2025b)	smelting and refining [331410]	content by the reference.				steel scrap. Because of this, the focus of this analysis is on primary refined nickel only.
Niobium	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in niobium content by the reference.	Not available	Not applicable	Not applicable	Niobium recycling does occur, but specific recycling quantities were not available.
Palladium	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in palladium content by the reference.	Automotive catalytic converter, jewelry, and electronics recycling	(SFA (Oxford) Ltd., 2024)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities were reported in palladium content by the reference. North American production data reported by the reference were allocated between the United States (two-thirds) and Canada (one-third). Western European production was allocated among relevant countries based on their reported refinery production less any mine production (U.S. Geological Survey, 2025b). Production in all other countries was allocated based on refinery production for India and the production capacity of South Korea (U.S. Geological Survey, 2025b), with the

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
								remainder being allocated to South Africa. Closed-loop recycling of palladium used in industrial applications (for example, catalysts) was excluded.
Phosphates	Marketable phosphate rock production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were converted from P ₂ O ₅ to elemental phosphorus using standard stoichiometric ratio. Chile's production, which was reported only in gross weight, was assumed to be 20% P ₂ O ₅ content. Although the production stage is focused on phosphate rock, trade data included processed phosphates.	Not applicable	Not applicable	Not applicable	Not applicable
Platinum	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in platinum content by the reference.	Automotive catalytic converter, jewelry, and electronics recycling	(SFA (Oxford) Ltd., 2024)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities were reported in platinum content by the reference. North American production data reported by the reference were allocated between the United States (two-thirds) and Canada (one-third). Western

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
								<p>European production was allocated among relevant countries based on their reported refinery production less any mine production (U.S. Geological Survey, 2025b). Production in all other countries was allocated based on refinery production for India and the production capacity of South Korea,(U.S. Geological Survey, 2025b) with the remainder being allocated to South Africa.</p> <p>Closed-loop recycling of platinum used in industrial applications (for example, catalysts) was excluded.</p>
Potash	Marketable potash production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were converted to elemental content based on the standard stoichiometric ratio.	Not applicable	Not applicable	Not applicable	Not applicable
Rhenium	Refinery production	(U.S. Geological Survey, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in rhenium content by the reference.	Secondary production (spent catalyst recycling and	(Roskill Information Services Ltd., 2019a; U.S. Geological	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Total secondary production reported by the U.S. Geological Survey (2024) was allocated to individual countries based on

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
					superalloy revert)	Survey, 2024)		their reported capacities (Roskill Information Services Ltd., 2019a).
Rhodium	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in rhodium content by the reference. Additionally, U.S. mine production was estimated separately based on previously (2014-2016) reported mining production in the mining company's annual report and an estimated rhodium-to-platinum-and-palladium production ratio of approximately 155:1 (Stillwater Mining Company, 2017).	Automotive catalytic converter recycling	(SFA (Oxford) Ltd., 2024)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities were reported in rhodium content by the reference. North American production data reported by the reference were allocated between the United States (two-thirds) and Canada (one-third). Western European production was allocated among relevant countries based on their reported platinum refinery production less any mine production (U.S. Geological Survey, 2025b). Production in all other countries was allocated based on rhodium refinery production for India and the remainder was allocated between South Africa and South Korea based on the secondary platinum production of these two countries estimated in this analysis.

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
								Closed-loop recycling of rhodium used in industrial applications (for example, catalysts) was excluded.
Ruthenium	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in ruthenium content by the reference. Additionally, U.S. mine production was estimated separately based on palladium mine production multiplied by the ruthenium-to-palladium ratio reported by Naldrett (2011).	End-of-life recycling	Refer to comment	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Closed-loop recycling of ruthenium from industrial applications (chemical catalysts and electrochemical applications) was excluded. Non-closed loop end-of-life recycling was estimated using the method described by Nassar (2015) and data from Johnson Matthey Plc (2024). The quantity that was estimated to be recycled at the end-of-life was allocated to individual countries based on the same proportions as platinum recycling.
Selenium	Refinery production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in selenium content by the reference. U.S. production data were withheld by the reference but used in this analysis.	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Silicon ferroalloys	Ferrosilicon production	(U.S. Geological Survey, 2025b)	Iron and steel mills and ferroalloy manufacturing [331110]	Quantities were assumed to be 65% silicon content on average.	Not applicable	Not applicable	Not applicable	Not applicable
Silicon metal	Metal production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were assumed to be 98% silicon content. U.S. production data were withheld by the reference but used in this analysis.	Not applicable	Not applicable	Not applicable	Not applicable
Silver	Mine production	(U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in silver content	Silver recycling (excludes new scrap)	(The Silver Institute and Metals Focus, 2025)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Secondary production reported by the reference by world regions was not disaggregated to individual country-level production due to lack of data.
Strontium	Celestite production	(U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were converted from celestite production to strontium content assuming 87% SrSO ₄ content for Iran's production and 92% SrSO ₄ content for all countries and the standard stoichiometric ratio (47.7%).	Not applicable	Not applicable	Not applicable	Not applicable
Tantalum	Mine production	(U.S. Geological Survey, 2025a)	Iron, gold, silver, and other metal ore	Quantities were reported in tantalum content by the reference. Due to	Secondary production	(Project Blue, 2025i)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding	Secondary production provided by the reference was for the world total. It was not

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
			mining [2122A0]	unusually low U.S. imports in 2023, data for tantalum were based on 2022 instead.			and alloying [331490]	possible to disaggregate by country. Data for tantalum were based on 2022 instead of 2023.
Tellurium	Refinery production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Due to changes in the domestic market, data for year 2024 were used instead of 2023. U.S. production was withheld by the reference but was estimated based on reported tellurium content in the anode slimes (Moats and others, 2019; Nassar and others, 2022).	Not applicable	Not applicable	Not applicable	It was assumed that end-of-life recycling of tellurium was negligible in 2024.
Tin	Primary smelter production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in tin content by the reference.	Secondary smelter production	(U.S. Geological Survey, 2025b)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities were reported in tin content by the reference.
Titanium ferroalloys	Ferrotitanium production	(Project Blue, 2025j)	Iron and steel mills and ferroalloy manufacturing [331110]	Quantities were reported in titanium content by the reference.	Not applicable	Not applicable	Not applicable	Not applicable
Titanium metal	Titanium melt supply	(Project Blue, 2025j)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and	Quantities were reported in titanium content by the reference.	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
			alloying [331490]					
Titanium mineral concentrates	Ilmenite, rutile, and titaniferous magnetite mine production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Other nonmetallic mineral mining and quarrying [2123A0]	Quantities were converted from TiO ₂ content to titanium content using the standard stoichiometric ratio (59.9%).	Not applicable	Not applicable	Not applicable	Not applicable
Titanium pigment	Titanium dioxide pigment production	(U.S. Geological Survey, 2024; U.S. Geological Survey, 2025a)	Synthetic dye and pigment manufacturing [325130]	Aside from the United States, for which production data were reported by the reference, production by country was estimated based on the reported production capacity multiplied by 80%. Quantities were converted from TiO ₂ content to titanium content using the standard stoichiometric ratio (59.9%).	Not applicable	Not applicable	Not applicable	Not applicable
Titanium sponge	Titanium sponge production	(U.S. Geological Survey, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were reported in titanium content by the reference. U.S. production data were withheld by the reference to avoid disclosing company proprietary data but used in this analysis.	Most titanium recycling is of revert scrap. End-of-life recycling was limited, and country specific	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
					data were not available. Recycling was thus excluded from the analysis.			
Tungsten	Mine production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities were reported in tungsten content by the reference.	Secondary tungsten production	(Project Blue, 2025k)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities, which were only reported by the reference as a total for the world, were disaggregated by country based on data on scrap production capacity, scrap consumption (Roskill Information Services Ltd., 2020) and trade of tungsten scrap (Zen Innovations AG, 2025).
Vanadium	Feedstock production	(Project Blue, 2025l)	Other basic inorganic chemical manufacturing [325180]	Feedstock production includes ores and concentrates, vanadium recovered from steel slags of vanadiferous iron ores, as well as vanadium recovered from ash, petroleum residues, and spent catalysts. Quantities were reported in vanadium content by the reference.	Not applicable	Not applicable	Not applicable	Not applicable

Mineral commodity	Primary production				Secondary production			
	Description	Data sources	Associated BEA industry [code]	Comments	Description	Data sources	Associated BEA industry [code]	Comments
Zinc, mined	Mine production	(U.S. Geological Survey, 2025b)	Copper, nickel, lead, and zinc mining [212230]	Quantities were reported in zinc content by the reference.	Not applicable	Not applicable	Not applicable	Not applicable
Zinc, smelted	Primary smelter	(U.S. Geological Survey, 2025b)	Nonferrous metal (except aluminum) smelting and refining [331410]	Quantities were assumed to be reported in zinc content by the reference.	Secondary smelter	(U.S. Geological Survey, 2025b)	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	Quantities were assumed to be reported in zinc content by the reference.
Zirconium	Mine production	(U.S. Geological Survey, 2025a; U.S. Geological Survey, 2025b)	Iron, gold, silver, and other metal ore mining [2122A0]	Quantities, which were reported in gross weight, were converted to zirconium content assuming an overall content of 48.1% based on 65% ZrO ₂ content and the standard stoichiometric ratio (74%) for all countries' production, except for Russian production, which was assumed to have an overall zirconium content of 72.6% based on 98% ZrO ₂ content and the standard stoichiometric ratio (74%).	Zirconium was recycled but no country-specific information was available.	Not applicable	Not applicable	Not applicable

World primary production capacity by country were based on the sources or assumptions noted in the following table. For secondary production and for the primary production all other mineral commodities, production capacities were estimated based on the 5-year maximum production divided by 80% (to simulate an assumed capacity utilization rate of 80%), unless noted in the following table. A ramp-up time of 6-months was also assumed to be required to increase production from current (year 2023) levels to the estimated capacities.

Table A1.2. World primary production capacity data sources.

Mineral commodity	Reference	Note
Alumina	(U.S. Geological Survey, 2025b)	Reference pertains to U.S. production capacity. Production capacities for all other countries were estimated using historical production as described above.
Aluminum	(U.S. Geological Survey, 2025a)	—
Arsenic	(U.S. Geological Survey, 2025a)	—
Copper, mined	(International Copper Study Group, 2024)	Production capacity for Tajikistan, which was not listed by the reference, was estimated using historical production as described above.
Copper, refined	(International Copper Study Group, 2024)	Production capacity for Laos, which was not listed by the reference, was estimated using historical production as described above.
Gallium	(Alonso and others, 2025)	—
Germanium	(Nassar and others, 2024)	—
Helium	(Alonso and others, 2025)	Production capacity for China, which was not listed by the reference, was assumed to equal to its 2023 production (U.S. Geological Survey, 2025a) divided by 80% to simulate a capacity utilization rate of 80%.
Indium	(U.S. Geological Survey, 2025b)	Production capacity for Uzbekistan, which was not listed by the reference, was estimated using historical production as described above. Production capacities were likely an underestimate given the lack of information on several refineries located in China, Japan, and Russia.
Iridium	Estimated	Production capacities for Canada, Russia, South Africa, United States, and Zimbabwe were estimated by the USGS platinum-group metal commodity specialists to be 0.5, 1.8, 8, 0.7, and 1 metric tons, respectively.
Iron ore	(U.S. Geological Survey, 2025b)	Reference pertains to U.S. production capacity. Production capacities for all other countries were estimated using historical production as described above.
Lead	(International Lead and Zinc Study Group, 2025a)	Refinery capacity reported by the reference was used in this analysis.
Magnesium compounds	(U.S. Geological Survey, 2025b)	—
Magnesium metal	(U.S. Geological Survey, 2025b)	—
Manganese alloys	(International Manganese Institute, 2024)	—
Manganese dioxide	(International Manganese Institute, 2024)	The capacity utilization rate reported by the reference was used along with 2023 production quantities to estimate the total capacity for each producing country.

Manganese metal	(International Manganese Institute, 2024)	The capacity utilization rate reported by the reference was used along with 2023 production quantities to estimate the total capacity for each producing country.
Manganese ore	(International Manganese Institute, 2024)	—
Manganese sulfate, high purity	(Project Blue, 2025e)	—
Niobium	(Project Blue, 2025f)	Reference pertains to production capacity for Brazil and Canada. Production capacity for all other countries was estimated using historical production as described above.
Palladium	(Alonso and others, 2025)	—
Platinum	(Alonso and others, 2025)	—
Potash	(Chtioui and Cross, 2023)	—
Rhenium	(Roskill Information Services Ltd., 2019a)	—
Rhodium	Estimated	Production capacities for Canada, Russia, South Africa, United States, and Zimbabwe were estimated by the USGS platinum-group metal commodity specialists to be 0.8, 3, 25, 0.4 and 1.9 metric tons, respectively.
Ruthenium	Estimated	Production capacities for Canada, Russia, South Africa, United States, and Zimbabwe were estimated by the USGS platinum-group metal commodity specialists to be 0.8, 3.8, 35, 0.4, and 1.5 metric tons, respectively.
Silver	(Kirilenko, 2023)	Production capacities were based on mine production potential by country. China's production capacity was estimated using historical production as described above due to lack of data.
Tin	(Roskill Information Services Ltd., 2019b)	—
Titanium sponge	(U.S. Geological Survey, 2024)	Production capacity refers to sponge production for yearend operating capacity.
Titanium pigment	(U.S. Geological Survey, 2024)	Production capacity refers to titanium pigment production for yearend operating capacity.
Zinc, smelter	(International Lead and Zinc Study Group, 2025b)	—

Rare earth production and production capacity estimation

Total separated rare earth production by country was obtained from Project Blue (2025g). To estimate the quantity by individual rare earth element, the rare earth disruptions noted by Nassar and others (2023) were used. Specifically:

- **China's** separated rare earth production was assumed be sourced from both domestic and foreign feedstock. China's domestically sourced feedstock production was delineated by company or source by Project Blue (2025g). Production of China Northern Rare Earths Group was assumed to have the rare earth distribution of Bayan Obo noted by Nassar and others (2023). The production of China Rare Earths Group (light rare earths) was assumed to have the rare earth distribution mix of Maoniuping, Weishanhu, and Dalucao in a combined mix that was proportional to each of their production noted by Nassar and others (2023). The production of China Rare Earths Group (heavy rare earths) was assumed to have the rare earth distribution of Jianghua noted by Nassar and others (2023). The production of Xiamen Tungsten was assumed to have the rare earth distribution of Huangfang and Jiazhuang noted by Nassar and others (2023). The production of Guangdong Rare Earth Group was assumed to have the rare earth distribution of Wufeng and Pingyuan noted by Nassar and others (2023). Production in excess of the authorized production quotas, referred to as "illegal" mining by Project Blue (2025g), was assumed to have the rare earth disruptions of the "undocumented" bastnaesite, monazite, and ion-adsorption clays in a combined mix that was proportional to each of their production noted by Nassar and others (2023). China's foreign sourced separated production was estimated as the difference between separated production and domestic feedstock production. It was assumed to have been predominately obtained from Myanmar and the Mountain Pass in the United States in proportions equal to their reported production for the year. The rare earth disruptions were also obtained from Nassar and others (2023).
- **Malaysia's** separated rare earth production was assumed be sourced entirely from Lynas Advanced Materials Plant. Two production quantities were reported on a quarterly fiscal-year basis: neodymium-praseodymium and total rare earth oxide ready for sale production quantities (Lynas Rare Earths Ltd., 2024). Although neodymium and praseodymium were produced as separated and a combined material, their production was allocated to these two elements based on the rare earth distribution for Mount Weld noted by Nassar and others (2023). Lanthanum and cerium production was assumed to be 95% of the difference between the total rare earth oxide and the neodymium-praseodymium production quantities given the rare earth distribution for Mount Weld noted by Nassar and others (2023). The remainder was not allocated given that no other rare earths were separated in Malaysia. Dysprosium and terbium separation was planned for 2025 (Lynas Rare Earths Ltd., 2025) but was excluded in this model which has a reference year of 2023.
- **Estonia's** separated rare earth production was assumed to be sourced entirely from loparite from Russia and was thus assumed to have the rare earth distribution of Lovozero as noted by Nassar and others (2023).

- **Japan’s and Vietnam’s** separated rare earth production was assumed to be from heavy mineral sands and was thus allocated to individual elements based on the rare earth distribution for typical monazite concentrate noted by Nassar and others (2023).
- **United States** separated rare earth production was assumed to be entirely from Mountain Pass. This production was reported to be entirely neodymium-praseodymium (MP Materials Corp., 2025). Although neodymium and praseodymium were produced as a combined material, their production was allocated to these two elements based on the rare earth distribution for Mountain Pass noted by Nassar and others (2023).

Total separated rare earth production capacities were obtained mainly from Roskill Information Services Ltd. (2021), with updated capacities for China Northern Rare Earths Group (Project Blue, 2025h) and Vietnam (Guarascio and Vu, 2023). China’s production capacity for “undocumented” production and production from foreign sourced ores were based on the 5-year maximum divided by 80%.

Production capacities were allocated to the individual rare earth elements using the same distributions noted above, except for the United States. United States’ rare earth distribution was assumed to be that of Mountain Pass but restricted to only the light rare earths lanthanum, neodymium, and praseodymium, excluding cerium (MP Materials Corp., 2025).

In addition to countries with reported production, France, India, and Thailand were also assumed to have production capacities despite not having reported production in 2023. France’s rare earth distribution was assumed to be the same as the weight-averaged of China. India’s rare earth distribution was assumed to be a distribution from India’s heavy mineral sands as noted by Nassar and others (2023) but renormalized to only include the light rare earths: lanthanum, cerium, neodymium, and praseodymium. Thailand’s rare earth distribution was assumed to be the same as Vietnam.

Secondary production, which was solely based on end-of-life recycling of neodymium-iron-boron permanent magnets, was obtained on information from Roskill Information Services Ltd. (2021) and Wood Mackenzie (2021).

All production and production capacity quantities were converted to elemental content based on standard stoichiometric ratios (Blue Line Corporation, 2025).

Domestic separated rare earth oxide production was assumed to be associated with the Basic inorganic chemical manufacturing [325180] industry. Domestic end-of-life recycling of permanent magnets was assumed to be associated with the “All Other Miscellaneous Fabricated Metal Product Manufacturing” [332999]

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Appendix 2. U.S. trade data of mineral commodities

U.S. net import sources for each mineral commodity in 2023 were determined using trade data obtained from Global Trade Tracker (Zen Innovations AG, 2025) using the Harmonized Tariff Schedule of the United States (HTS) or Schedule B trade codes for each mineral commodity noted in the following table. Trade data were obtained from the U.S. perspective (meaning, as reported by the United States) for both imports and exports. Imports and exports were both calculated net of re-imports and re-exports, respectively. The table also includes the assumed elemental content for each trade code, which allowed for summation across trade codes for each mineral commodity.

For scrap materials, any trade transaction with an average unit value equal to or greater than the reported price of mineral commodity was assumed to be 100% and anything lower was assumed to have content that was proportionally lower. For example, if the unit value was half the price of mineral commodity, then it was assumed to be 50% content. Similarly, trade codes that contain more than one mineral commodity were apportioned to the individual mineral commodities based proportionally on their unit value. This approach was used wherever the content was described as determined “based on the unit value of each trade transaction” in the table.

Quantities were estimated for trade transactions where only the monetary values were provided by assuming the transactions had the same value-weighted average unit value for the trade code (or the nearest trade code if no other trade transactions were reported).

Because of complexity regarding their trade, rare earth elements are addressed separately at the end of this appendix.

Table A2.1. Trade codes use for each mineral commodity. HTS = Harmonized Tariff Schedule of the United States

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
Alumina	281820	0.529	281820	0.529	
	281830	0.346	281830	0.346	
Aluminum	760110	1	760110	1	Trade codes of aluminum products (for example, bars, plates, rods, and wires) were excluded as these products were outputs of the U.S. Bureau of Economic Analysis industry that aluminum was connected to in the model.
	760120	1	760120	1	
	760310	1	760310	1	
	760320	1	760320	1	
					Trade of aluminum scrap (trade code: 760200) was excluded because domestic secondary production was included in the analysis and net imports of aluminum scrap was negative.

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
Antimony	282580 811010 811020 811090	0.835 1 1 1	282580 811010 811020 811090	0.835 1 1 1	Trade of antimony ores and concentrates [trade code 261710] was excluded because the primary production process used this analysis was that of the smelters, downstream of the mining of ores and concentrates. Trade of antimonial lead under HTS code 780191 was also excluded as that use of antimony was largely sufficient through closed-loop recycling.
Arsenic	2804800000 2811191000 2811291000 2853909010 3818000010	1 0.518 0.518 0.757 0.528	2804800000 2853909010 28539030009 38180010308 38180010709	1 0.518 0.518 0.518 0.608	Sufficiently disaggregated export data for arsenic contained in wafers were not available for the United States. Instead, the exports used in this analysis were those of the U.S. trade partners. Because the trade of gallium arsenide [trade codes 2853909010, 3818000010, 28539030009, 38180010308] and gallium aluminum arsenide [38180010709] wafers may include low-value scrap materials, their respective trade codes were split from scrap based the unit value of each trade transaction.
Barite	2511105000 2511101000	0.588	2511100000	0.588	
Bauxite	260600	Content was assumed to vary by country. Quantities were converted to aluminum content based on Al ₂ O ₃ content of bauxite ore grades reported	260600	Content was assumed to vary by country. Quantities were converted to aluminum content based on Al ₂ O ₃ content of bauxite ore	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
		in (Liu and Müller, 2013) and the standard stoichiometric ratio (~52.9%). For countries not included by the reference, the Al ₂ O ₃ content of bauxite was assumed to be 41%.		grades reported in (Liu and Müller, 2013) and the standard stoichiometric ratio (~52.9%). For countries not included by the reference, the Al ₂ O ₃ content of bauxite was assumed to be 41%.	
Beryllium	2825901000 7405006030 7409901030 7409905030 7409909030 8112120000 8112130000 8112190000	0.360 0.040 0.040 0.040 0.040 1 1 1	8112120000 8112130000 8112190000	1 1 1	No trade data were reported under the trade code for beryllium ores and concentrates [2617900030] since 2021.
Bismuth	28259021 2834290500 2836992000 3824993100 8106100000 8106900000	0.897 0.431 0.778 1 1 1	2834290500 2836992000 8106100000 8106900000	0.119 0.778 1 1	U.S imports of bismuth trioxide [trade code: 2825902] were based on China's net exports to the United States (mirror trade). Based on their unit values, U.S. exports of bismuth nitrates were assumed to be sold in a concentration solution with a 22.5% bismuth nitrate content (Shepherd Chemical, 2024).
Cadmium	2825907500 8112610000 8112691000 8112699000	0.875 1 1 1	2830902000 8112610000 8112691000 8112699000	0.778 1 1 1	The cadmium content of traded scrap [trade code: 811261000] was determined based on the unit value of each trade transaction.
Chromite	2610000020 2610000040 2610000060	1 1 1	2610000000	0.290	Chromite ore imports were reported in chromium content under the secondary units.
Chromium chemicals	2841501000 2841300000 2841509100	0.284 0.349 0.311	2833294000 2841501000 2841509100	0.168 0.284 0.311	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
	2819900000 2819100000 2833294000	0.684 0.520 0.168	2841904500	0.195	
Chromium ferroalloys	7202410000 7202491000 7202495010 7202495090 7202500000	1 1 1 1 1	7202410000 7202490000 7202500000	1 1 1	Trade of ferrochromium was reported in chromium content. Notable quantities of chromium were also traded within embedded stainless steel but excluded from this analysis.
Chromium metal	8112210000 8112220000 8112290000	1 1 1	8112210000 8112220000 8112290000	1 1 1	The chromium content of traded scrap [trade code: 8112220000] was determined based on the unit value of each trade transaction.
Cobalt chemicals	28429030 28429060 28539030 28539050 2822000000 2827396000 2833291000 2836991000 2841909010 2841909020 2841909040 2915293000	0.097 0.064 0.092 0.136 0.720 0.250 0.270 0.460 0.600 0.097 0.059 0.240	28429030 28429060 28539030 2822000000 2827396000 2841909020 2841909030 2841909040 2915293000	0.097 0.064 0.092 0.753 0.750 0.097 0.064 0.059 0.240	Trade of cobalt containing lithium-ion battery cathode materials were obtained from the mirror trade as reported by China under trade codes 28429030, 28429060, 28539030, and 28539050, and South Korea under trade codes 2841909010, 2841909020, 2841909030 and 2841909040.
Cobalt metal	8105203000 8105206000 8105209000 8105300000 8105900000 8505110050 8505110070	1 1 1 1 1 0.680 0.018	8105200000 8105300000 8105900000 8505110070	1 1 1 0.018	The cobalt content of traded scrap [trade code: 8105300000] was determined based on the unit value of each trade transaction.
Copper, mined	2603000010	1	2603000010	1	
Copper, refined	740311 740312 740313 740319	1 1 1 1	740311 740312 740313 740319	1 1 1 1	
Feldspar	2529100000	1	2529100000	1	
Fluorspar, acid spar	2529220000 2530901000 2811110000 2826120000 2826300000	0.477 0.543 0.983 0.679 0.543	2529220000 2530901000 2811110000 2826120000 2826300000	0.477 0.543 0.983 0.679 0.543	
Fluorspar, metspar	2529210000	0.457	2529210000	0.457	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
Gallium	2853909010 3818000010 8112921000	0.482 0.482 1	81129990 2853909010 28539030009 38180010308 38180010709	1 0.482 0.482 0.482 0.283	<p>Sufficiently disaggregated export data for gallium were not available for the United States. Instead, the exports used in this analysis were those of the U.S. trade partners.</p> <p>Because the trade of gallium arsenide [trade codes: 2853909010, 28539030009, 3818000010, 38180010308] and gallium aluminum arsenide [trade code: 38180010709] wafers may include low-value scrap materials, their respective trade codes were split from scrap based the unit value of each trade transaction.</p>
Germanium	2825600000 2827399000 8112926000 8112926100 8112926500 8112991000	0.694 0.345 1 1 1 1	2825600000 8112926100 8112991000	0.694 1 1	<p>Trade of germanium oxide [trade code: 2825600000], germanium chloride [trade code: 2827399000], and germanium scrap [trade code: 8112991000] were split from zirconium, other chlorides, and scrap material codes based on the unit value of each trade transaction. The price of the other chlorides was assumed to be \$300 per kg (Nassar and others, 2024).</p>
Gold	2603000050 2608000050 2616100080 2616900040 7108110000 7108121010 7108121013 7108121017 7108121020 7108125000 7108125010 7108125050 7108135000 7108135500 7108137000	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2603000050 2608000050 2616100080 2616900040 7108110000 7108121010 7108121013 7108121017 7108121020 7108125000 7108125010 7108125050 7108135000 7108135500 7108137000	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
Graphite, natural	250410	1	250410	1	
	250490	1	250490	1	
Graphite, synthetic	380110	1	380110	1	
	380120	1	380120	1	
	380190	1	380190	1	
Hafnium	8112310000	1	8112310000	1	Hafnium traded under trade code 8112310000 may have included low-value scrap materials. The trade was split from scrap based the unit value of each trade transaction.
	8112390000	1	8112390000	1	
Helium	2804290010	1	2804290010	1	
Indium	8112923000	1	81129281	1	Sufficiently disaggregated export data for indium were not available for the United States. Instead, exports HTS codes and the export data used in this analysis were those of the U.S. trade partners.
			81129930	1	
			8112923000	1	
			8112925000	1	
			38180010601	0.605	
Iridium	7110410010	1	7110410000	1	For trade codes 7110410000, 7110410050 and 7110490000, elemental content was allocated between ruthenium and iridium based on unit value of each trade transaction. Osmium content was assumed to be negligible.
	7110410050	1	7110490000	1	
	7110490010	1			
Iron ore	260111	0.662	260111	0.662	
	260112	0.636	260112	0.636	
	260120	0.777	260120	0.777	
Lead	7801100000	1	7801100000	1	Trade of lead ores and concentrates are excluded given that the analysis starts with refined lead. Moreover, there was no primary lead production in the United States in 2023. The lead content of lead waste and scrap [trade codes 7802000030 and 7802000060] was determined based on the unit value of each trade transaction.
	7801999030	1	7801993000	1	
	7801999050	1	7801999030	1	
	7802000030	1	7801999050	1	
	7802000060	1	7802000030	1	
			7802000060	1	
Lithium	28429030	0.071	28429030	0.071	Trade of lithium containing lithium-ion battery cathode
	28429060	0.072	28429060	0.072	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
	2825200000 2836910010 2836910050 2841909010 2841909020 2841909040	0.170 0.188 0.188 0.071 0.071 0.069	2825200000 2836910010 2836910050 2841909020 2841909030 2841909040	0.170 0.188 0.188 0.071 0.072 0.069	materials were obtained from the mirror trade as reported by China under trade codes 28429030, and 28429060 and South Korea under trade codes 2841909010, 2841909020, 2841909030 and 2841909040.
Magnesium compounds	2519100000 2519901000 2519902000 2519905000 2530201000 2530202000 2816100000 2827310000 2833210000	0.288 0.603 0.603 0.603 0.176 0.099 0.417 0.255 0.202	2519100000 2519901000 2519902000 2519905000 2530200000 2816100000 2827310000 2833210000	0.288 0.603 0.603 0.603 0.099 0.417 0.255 0.202	
Magnesium metal	8104110000 8104190000 8104200000 8104300000 8104900000	1 1 1 1 1	8104110000 8104190000 8104200000 8104300000 8104900000	1 1 1 1 1	The magnesium metal content of magnesium waste and scrap [trade code: 8104200000] was determined based on the unit value of each trade transaction. Due to data being withheld, trade data from Turkey [trade code: 8104110000] were obtained as reported by Turkey.
Manganese alloys	7202111000 7202115000 7202191000 7202195000 7202300000	1 1 1 1 1	7202110000 7202190000 7202300000	1 1 1	Quantities were reported in manganese content.
Manganese dioxide	2820100000	1	2820100000	1	Quantities were reported in manganese content. Trade of other manganese oxides (excluding dioxides) under trade code 2820900000 were excluded from the analysis.
Manganese metal	8111003000 8111004700 8111004910 8111004990 8111006000	1 1 1 1 1	8111000000	1	The manganese metal content of manganese waste and scrap [trade codes: 8111003000 and 8111000000] was determined based on the

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
					unit value of each trade transaction.
Manganese ore	2602000040 2602000060	1 1	2602000000	0.350	Manganese ore imports were reported in contained manganese under the secondary units.
Manganese sulfate (high purity)	28429030 28539030 2841909020 2841909040	0.074 0.059 0.074 0.055	28429030 28539030 2841909020 2841909040	0.074 0.059 0.074 0.055	Trade of manganese sulfate under trade code 2833295110 only began to be reported in 2025 and includes standard grade manganese sulfate. It was therefore excluded from the analysis. Trade of manganese containing lithium-ion battery cathode materials were obtained from the mirror trade as reported by China under trade codes 28429030 and 28539030, and South Korea under trade codes 2841909020, and 2841909040.
Mica	2525100050 2525200000 2525300000	1 1 1	2525200000 2525300000	1 1	Mica, except split block, splittings, powder and waste [trade code: 2525100050] was split between scrap and flake and sheet mica based on the unit value of each trade transaction.
Molybdenum	2613100000 2613900000 2825700000 2841701000 2841705000 3206200020 3824993400 7202700000 8102100000 8102940000 8102953000 8102956000 8102960000 8102970000 8102990000	1 1 0.667 1 1 0.027 1 1 1 1 1 1 1 1 1	2613100000 2613900000 2825700000 2841700000 7202700000 8102100000 8102940000 8102950000 8102960000 8102970000 8102990000	1 1 0.67 1 1 1 1 1 1 1 1 1 1 1	The molybdenum content of molybdenum waste and scrap [trade code: 8102970000] was determined based on the unit value of each trade transaction. Similarly, the molybdenum content of the roasted [trade code: 2613100000] and unroasted [trade code: 2613900000] concentrate, although presumably reported in molybdenum content, was determined based on the unit value of each trade transaction.
Nickel, mined	2604000040	1	2604000040	1	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
Nickel, primary refined	28429030	0.428	28429030	0.428	Trade of nickel containing lithium-ion battery cathode materials was obtained from the mirror trade as reported by China under trade codes 28429030, 28429060, 28539030, and 28539050, and South Korea under trade codes 2841909020, 2841909030 and 2841909040. The nickel content of nickel waste and scrap [trade code: 7503000000] was determined based on the unit value of each trade transaction.
	28429060	0.508	28429060	0.508	
	28539030	0.489	28539030	0.489	
	28539050	0.408	2604000040	1	
	2604000040	1	2833240000	0.229	
	2833240000	0.229	2841909020	0.428	
	2841909020	0.428	2841909030	0.489	
	2841909030	0.489	2841909040	0.470	
	2841909040	0.470	7202600000	1	
	7202600000	1	7501100000	1	
	7501100000	1	7501200000	1	
	7501200000	1	7502100000	1	
	7502100000	1	7502200000	1	
	7502200000	1	7503000000	1	
	7503000000	1			
Niobium	2615903000	0.196	2615903000	0.196	Niobium content of niobium ores and concentrates [trade code: 2615906030], tantalum ores and concentrates [trade code: 2615906030], and synthetic concentrate [trade code: 2615903000] was split between niobium and tantalum based on the unit value of each trade transaction.
	2615906030	0.070	2615906030	0.070	
	2615906060	0.070	2615906060	0.070	
	2825901500	0.699	7202930000	0.630	
	7202934000	0.630			
	7202938000	0.630			
	8112924000	1			
Palladium	711021	1	711021	1	
	711029	1	711029	1	
Phosphates	2510100000	0.122	2510100000	0.122	
	2510200000	0.122	2510200000	0.122	
	2835250000	0.195	2835250000	0.195	
	2835260000	0.175	2835260000	0.175	
	3103110000	0.199	3103110000	0.199	
	3103190000	0.079	3103190000	0.079	
	3105300000	0.201	3105300000	0.201	
	3105400010	0.266	3105400000	0.266	
	3105400050	0.100			
Platinum	711011	1	711011	1	The platinum content of platinum waste and scrap [trade code: 711292] was determined based on the unit value of each trade transaction.
	711019	1	711019	1	
	711292	1	711292	1	
Potash	2834210000	0.374	2834210000	0.374	
	3104200010	0.506	3104200000	0.515	
	3104200050	0.523	3104300000	0.423	
	3104300000	0.423	3104900100	0.116	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
	3104900100	0.116			
Rhenium	2841902000 8112415000 8112490000	0.694 1 1	8112410000 8112490000	1 1	The rhenium content of rhenium waste and scrap [trade code: 8112410000] was determined based on the unit value of each trade transaction.
Rhodium	711031 711039	1 1	711031 711039	1 1	
Ruthenium	7110410030 7110410050 7110490050	1 1 1	7110410000 7110490000	1 1	For the applicable trade codes 7110410000 7110410050 7110490000, content was allocated between ruthenium and iridium based on unit value of each trade transaction. For trade code 7110490050, content was allocated between ruthenium based on unit value of each trade transaction.
Selenium	2804900000 2811292000	1 0.695	2804900000	1	
Silicon ferroalloys	7202211000 7202215000 7202219000 7202290010 7202290050	1 1 1 1 1	7202210000 7202290000	1 1	Quantities were reported in silicon content under the secondary units.
Silicon metal	2804610000 2804691000 2804695000	1 0.995 0.980	2804610000 2804691000 2804695000	1 0.995 0.980	
Silver	2603000040 2607000040 2608000040 2616100040 2620300040 2843210000 2843290100 7106100000 7106911010 7106911020 7106915000 7106921000 7106925000 7112990100	1 1 1 1 1 0.635 0.574 1 1 1 1 1 1 1	2616100040 2843210000 2843290100 7106100000 7106911010 7106911020 7106915000 7106920000 7112990100	1 0.635 0.574 1 1 1 1 1 1	The silver content of silver waste and scrap [trade code: 7112990100] was determined based on the unit value of each trade transaction.
Strontium	2530908010 2805191000 2816401000 2834292000 2836920000	0.439 1 0.700 0.414 0.594	2816401000 2836920000 8505110030	0.700 0.594 0.059	Trade of ceramic ferrite permanent magnets [trade code 8505110030] was determined to be entirely strontium (rather than

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
	8505110030	0.059			barium) ferrite permanent magnets based on the unit values of each trade transaction. Ferrite permanent magnet composition was assumed to be 10% strontium carbonate (Magnet Applications, 2024)
Tantalum	2615903000 2615906030 2615906060 8103200030 8103200090 8103300000 8103910000 8103990000	0.409 0.229 0.262 1 1 1 1 1	2615903000 2615906030 2615906060 8103200030 8103200090 8103300000 8103910000 8103990000	0.409 0.229 0.262 1 1 1 1 1	Tantalum content of tantalum waste and scrap [trade codes: 8103300000; 2615903000] was determined based on the unit value of each trade transaction. Tantalum content of niobium ores and concentrates [trade code 2615906030], tantalum ores and concentrates [trade code 2615906030], and synthetic concentrate [trade code 261590300] was split between niobium and tantalum based on the unit value of each trade transaction.
Tellurium	2804500020	1	2804500020	1	
Tin	8001100000 8001200010 8001200050 8001200090 8002000000	1 0.90 1 1 1	8001100000 8001200000 8002000000	1 0.90 1	Tin content of tin waste and scrap [trade code: 8002000000] was determined based on the unit value of each trade transaction.
Titanium ferroalloys	7202910000	0.70	7202910000	0.70	
Titanium metal	8108200015 8108200030 8108200095 8108903030 8108903060 8108906020 8108906031 8108906045 8108906060 8108906075	1 1 1 1 1 1 1 1 1 1	8108200030 8108200090 8108906020 8108906031 8108908000	1 1 1 1 1	
Titanium mineral concentrates	2614003000 2614006020 2614006040 2620995000	0.563 0.360 0.360 0.509	2614000000	0.360	
Titanium pigment	2823000000	0.599	2823000000	0.599	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
	3206110000	0.509	3206110000	0.509	
	3206190000	0.479	3206190000	0.479	
Titanium sponge	8108200010	1	8108200010	1	Titanium content of titanium waste and scrap [trade code: 8108300000] was determined based on the unit value of each trade transaction.
	8108300000	1	8108300000	1	
Tungsten	2611003000	1	2611000000	0.515	Tungsten content of tungsten waste and scrap [trade code: 810197] and slag, ash, and residues [trade code: 2620992000] was determined based on the unit value of each trade transaction.
	2611006000	1	2841800010	1	
	2620992000	1	2841800040	1	
	2825903000	1	2849903000	1	
	2827394000	0.464	7202800000	0.770	
	2841800010	1	810110	1	
	2841800050	1	810194	1	
	2849903000	1	810196	1	
	3824993500	1	810197	1	
	7202800000	0.770	810199	1	
	810110	1			
	810194	1			
	810196	1			
	810197	1			
	810199	1			
Vanadium	2615906090	0.560	2615906090	0.560	
	2620400030	0.560	2620991000	1	
	2825300010	1	2825300010	1	
	2825300050	1	2825300050	1	
	2827391000	1	7202920000	0.100	
	2827491000	1	7601209030	1	
	2833293000	1	8112927000	1	
	2841901000	1	8112992000		
	2850002000	1			
	7202920000	1			
	7601209030	0.100			
	8112927000	1			
	8112992000	1			
Zinc, mined	2607000030	1	2608000030	1	
	2608000030	1			
Zinc, smelted	2817000000	0.803	2817000000	0.803	Zinc content of zinc waste and scrap [trade code: 7902000000] was determined based on the unit value of each trade transaction.
	2833294500	0.405	2833294500	0.405	
	7901110000	1	7901110000	1	
	7901121000	1	7901120000	1	
	7901125000	1	7901200000	0.7	
	7901200000	0.7	7902000000	1	
	7902000000	1			
Zirconium	2615100000	0.481	2615100000	0.481	Zirconium content of zirconium ores and concentrates [trade code: 2615100000] were assumed to be 48.1% zirconium content for trade
	2825600000	0.740	2825600000	0.740	
	7202991000	0.367	7202991000	0.367	
	8109210000	1	8109210000	1	
	8109290000	1	8109290000	1	
	8109310000	1	8109310000	1	

Mineral commodity	Imports		Exports		Comments
	HTS code	Assumed content	Schedule B code	Assumed content	
	8109390000 8109910000 8109990000	1 1 1	8109390000 8109910000 8109990000	1 1 1	<p>with all countries except Russia, for which the content was assumed to be 72.6%.</p> <p>Trade of zirconium oxide [trade code: 2825600000] were split from germanium based on the unit value of each trade transaction.</p> <p>The zirconium content of the trade of zirconium waste and scrap [trade codes 8109310000 and 8109390000] was determined based on the unit value of each trade transaction.</p> <p>The zirconium content of ferrozirconium was estimated based on the geometric mean of the minimum and maximum reported contents.</p>

Trade of rare earth elements

Trade data for rare earth elements were reported under various trade codes, many of which contain several rare earth elements in a single code. For example, trade code 2846902084 “mixtures of rare-earth, except cerium chlorides, not elsewhere specified or included”, likely contains several rare earth element compounds. Because the analysis requires that each rare earth element to be treated as a separate commodity, the following estimation procedures were used to disaggregate the trade flows for trade codes that contain multiple rare earth elements.

- U.S. imports of rare earth elements from China were obtained based on China’s reported exports to the United States because China has several trade codes that report trade of individually named rare earth elements. For U.S. imports from China under Chinese trade codes that do not identify an individual rare earth element by name, the trade data were disaggregated by matching a rare earth element with the closest reported price to the unit value of each trade transaction. These trade codes are noted in Table A2.2 along with their assumed elemental contents, which were based on standard stoichiometric ratios for the different compounds.
- U.S. imports from countries other than China and all U.S. exports were obtained as reported by the United States using U.S. trade codes. Trade codes with individually named rare earth element, metals or compounds, were allocated to their named elements. For trade codes without individually named rare earth element (such as mixtures), the allocation to individual rare earth elements was based on the rare earth element distribution typical of monazite concentrates as noted by Nassar and others (2023), except for the imports from Malaysia and Estonia under trade code 2846908090 “compounds, organic or inorganic, of rare earth metals, of yttrium or of scandium, or mixtures of these metals, not elsewhere specified or indicated”, for which the rare earth distributions of these countries’ respective productions (as noted in appendix 1) were used instead. The specific allocations and elemental content conversions based on standard stoichiometric ratios for the different compounds are noted in Table A2.3.
- The trade of sintered rare earth permanent magnets (8505110050 “sintered samarium-cobalt permanent magnets and articles intended to become permanent magnets after magnetization”; 8505110070 “sintered neodymium-iron-boron permanent magnets and articles intended to become permanent magnets after magnetization”) was included in this analysis. The specific allocations of individual rare earth elements are also noted in Table A2.3. Trade data for samarium-cobalt magnets were obtained for year 2024 instead of 2023 as the quantity of U.S. imports of these magnets have notably declined since first reported in 2022.
- U.S. exports of rare earth ores and concentrates from both the Mountain Pass mine and from heavy mineral sands operations under trade codes 2846909000 “compounds, organic or inorganic, of rare earth metals, of yttrium or of scandium, or mixtures of these metals, excluding cerium, not elsewhere specified or indicated” and 2612200000 “thorium ores and concentrates” were excluded as the system boundaries for the analysis began at the refining stage.

Table A2.2 U.S. imports of rare earth elements from China, as reported by China

Mineral commodity	China's trade code	Rare earth element fraction	Elemental content	Overall elemental content
Cerium	28053015	1.000	1.000	1.000
Cerium	28461030	1.000	0.609	0.609
Cerium	28461020	1.000	0.673	0.673

Mineral commodity	China's trade code	Rare earth element fraction	Elemental content	Overall elemental content
Cerium	28461010	1.000	0.814	0.814
Cerium	36069011	0.514	0.888	0.457
Cerium	36069019	0.514	0.888	0.457
Cerium	28469029	1.000	0.568	0.568
Cerium	28469028	1.000	0.609	0.609
Dysprosium	28469032	1.000	0.851	0.851
Dysprosium	28469015	1.000	0.871	0.871
Dysprosium	28053012	1.000	1.000	1.000
Dysprosium	28469094	1.000	0.404	0.404
Erbium	28469019	0.173	0.875	0.152
Europium	28469014	1.000	0.864	0.864
Europium	28469099	0.298	0.388	0.115
Gadolinium	28469019	0.349	0.868	0.303
Gadolinium	28469039	0.936	0.734	0.687
Holmium	28469019	0.041	0.873	0.036
Holmium	28469049	0.196	0.647	0.127
Holmium	28469099	0.001	0.408	0.001
Lanthanum	28469041	1.000	0.607	0.607
Lanthanum	28469023	1.000	0.566	0.566
Lanthanum	28469012	1.000	0.853	0.853
Lanthanum	28053014	1.000	1.000	1.000
Lanthanum	28469091	1.000	0.367	0.367
Lanthanum	36069011	0.267	0.888	0.237
Lanthanum	36069019	0.267	0.888	0.237
Lutetium	28469018	1.000	0.879	0.879
Lutetium	28469099	0.055	0.422	0.023
Neodymium	28469044	1.000	0.616	0.616
Neodymium	28469024	1.000	0.576	0.576
Neodymium	28469034	1.000	0.717	0.717
Neodymium	28469013	1.000	0.857	0.857
Neodymium	28053011	1.000	1.000	1.000
Neodymium	28469019	0.050	0.857	0.043
Neodymium	36069011	0.165	0.888	0.146
Neodymium	36069019	0.165	0.888	0.146
Praseodymium	28469035	1.000	0.712	0.712
Praseodymium	28053016	1.000	1.000	1.000
Praseodymium	28469017	1.000	0.828	0.828
Praseodymium	28469019	0.016	0.828	0.013
Praseodymium	36069011	0.051	0.888	0.046
Praseodymium	36069019	0.051	0.888	0.046
Samarium	28469019	0.165	0.862	0.142
Samarium	28469039	0.064	0.725	0.046
Samarium	36069011	0.002	0.888	0.002

Mineral commodity	China's trade code	Rare earth element fraction	Elemental content	Overall elemental content
Samarium	36069019	0.002	0.888	0.002
Terbium	28469016	1.000	0.850	0.850
Terbium	28053013	1.000	1.000	1.000
Thulium	28469019	0.145	0.876	0.127
Thulium	28469099	0.007	0.413	0.003
Ytterbium	28469019	0.061	0.878	0.054
Ytterbium	28469049	0.804	0.658	0.529
Ytterbium	28469099	0.638	0.243	0.155
Yttrium	28469046	1.000	0.497	0.497
Yttrium	28469026	1.000	0.455	0.455
Yttrium	28053017	1.000	1.000	1.000
Yttrium	28469011	1.000	0.787	0.787
Yttrium	28469096	1.000	0.271	0.271

Table A2.3 U.S. exports and U.S. imports of rare earth elements countries other than China, as reported by the United States

Mineral commodity	Trade code	Rare earth fraction	Elemental content	Overall elemental content
Cerium	2805300000	0.400	0.400	0.160
Cerium	2805300010	1.000	1.000	1.000
Cerium	2846100000	1.000	0.464	0.464
Cerium	2846100010	1.000	0.814	0.814
Cerium	2846100050	1.000	0.464	0.464
Cerium	2846908090	0.400	0.400	0.160
Cerium	3606900000	0.514	0.457	0.235
Cerium	3606903000	0.514	0.457	0.235
Cerium	8505110070	0.320	0.063	0.020
Dysprosium	2805300000	0.004	0.004	1.6E-05
Dysprosium	2805300050	0.043	0.043	0.002
Dysprosium	2805300090	0.043	0.043	0.002
Dysprosium	2846902040	0.007	0.006	4.0E-05
Dysprosium	2846902060	0.007	0.003	2.1E-05
Dysprosium	2846902084	0.007	0.003	2.3E-05
Dysprosium	2846908075	0.013	0.006	8.4E-05
Dysprosium	2846908090	0.004	0.004	1.6E-05
Dysprosium	8505110070	0.320	0.029	0.009
Erbium	2805300000	0.001	0.001	1.0E-06
Erbium	2805300050	0.011	0.011	1.2E-04
Erbium	2805300090	0.011	0.011	1.2E-04
Erbium	2846902040	0.002	0.001	2.5E-06
Erbium	2846902060	0.002	0.001	1.4E-06
Erbium	2846902084	0.002	0.001	1.5E-06
Erbium	2846908075	0.003	0.002	5.4E-06

Mineral commodity	Trade code	Rare earth fraction	Elemental content	Overall elemental content
Erbium	2846908090	0.001	0.001	1.0E-06
Europium	2805300000	0.006	0.006	3.6E-05
Europium	2805300050	0.065	0.065	0.004
Europium	2805300090	0.065	0.065	0.004
Europium	2846902040	0.010	0.009	8.8E-05
Europium	2846902060	0.011	0.004	4.4E-05
Europium	2846902084	0.010	0.005	4.9E-05
Europium	2846908075	0.019	0.009	1.8E-04
Europium	2846908090	0.006	0.006	3.6E-05
Gadolinium	2805300000	0.022	0.022	4.8E-04
Gadolinium	2805300050	0.238	0.238	0.057
Gadolinium	2805300090	0.238	0.238	0.057
Gadolinium	2846902040	0.037	0.032	0.001
Gadolinium	2846902060	0.040	0.015	0.001
Gadolinium	2846902084	0.038	0.018	0.001
Gadolinium	2846908075	0.072	0.034	0.002
Gadolinium	2846908090	0.022	0.022	4.8E-04
Gadolinium	8505110050	0.057	0.063	0.020
Gadolinium	8505110070	0.320	0.019	0.006
Holmium	2805300000	0.001	0.001	1.0E-06
Holmium	2805300050	0.011	0.011	1.2E-04
Holmium	2805300090	0.011	0.011	1.2E-04
Holmium	2846902040	0.002	0.001	2.5E-06
Holmium	2846902060	0.002	0.001	1.4E-06
Holmium	2846902084	0.002	0.001	2.1E-06
Holmium	2846908075	0.003	0.002	5.3E-06
Holmium	2846908090	0.001	0.001	1.0E-06
Lanthanum	2805300000	0.280	0.280	0.078
Lanthanum	2805300005	1.000	1.000	1.000
Lanthanum	2846902005	1.000	0.853	0.853
Lanthanum	2846902040	0.468	0.398	0.186
Lanthanum	2846902060	0.451	0.174	0.079
Lanthanum	2846902084	0.463	0.218	0.101
Lanthanum	2846908070	1.000	0.462	0.462
Lanthanum	2846908090	0.280	0.280	0.078
Lanthanum	3606900000	0.267	0.237	0.064
Lanthanum	3606903000	0.267	0.237	0.064
Lanthanum	8505110070	0.320	0.017	0.005
Lutetium	2805300000	1.0E-04	1.0E-04	1.0E-08
Lutetium	2805300050	0.001	0.001	1.2E-06
Lutetium	2805300090	0.001	0.001	1.2E-06
Lutetium	2846902040	1.7E-04	1.5E-04	2.5E-08
Lutetium	2846902060	1.9E-04	7.5E-05	1.4E-08

Mineral commodity	Trade code	Rare earth fraction	Elemental content	Overall elemental content
Lutetium	2846902084	2.2E-04	1.0E-04	2.2E-08
Lutetium	2846908075	3.5E-04	1.6E-04	5.6E-08
Lutetium	2846908090	1.0E-04	1.0E-04	1.0E-08
Neodymium	2805300000	0.160	0.160	0.026
Neodymium	2805300020	1.000	1.000	1.000
Neodymium	2846902040	0.269	0.228	0.061
Neodymium	2846902060	0.277	0.107	0.030
Neodymium	2846902084	0.271	0.128	0.035
Neodymium	2846908075	0.504	0.235	0.119
Neodymium	2846908090	0.160	0.160	0.026
Neodymium	3606900000	0.165	0.146	0.024
Neodymium	3606903000	0.165	0.146	0.024
Neodymium	8505110070	0.320	0.712	0.228
Praseodymium	2805300000	0.068	0.068	0.005
Praseodymium	2805300015	1.000	1.000	1.000
Praseodymium	2846902040	0.110	0.094	0.010
Praseodymium	2846902060	0.116	0.045	0.005
Praseodymium	2846902084	0.113	0.053	0.006
Praseodymium	2846908075	0.212	0.099	0.021
Praseodymium	2846908090	0.068	0.068	0.005
Praseodymium	3606900000	0.051	0.046	0.002
Praseodymium	3606903000	0.051	0.046	0.002
Praseodymium	8505110070	0.320	0.155	0.050
Samarium	2805300000	0.029	0.029	0.001
Samarium	2805300050	0.314	0.314	0.099
Samarium	2805300090	0.314	0.314	0.099
Samarium	2846902040	0.049	0.042	0.002
Samarium	2846902060	0.051	0.020	0.001
Samarium	2846902084	0.049	0.023	0.001
Samarium	2846908075	0.093	0.044	0.004
Samarium	2846908090	0.029	0.029	0.001
Samarium	3606900000	0.002	0.002	4.8E-06
Samarium	3606903000	0.002	0.002	4.8E-06
Samarium	8505110050	0.290	0.930	0.268
Terbium	2805300000	0.001	0.001	1.0E-06
Terbium	2805300050	0.011	0.011	1.2E-04
Terbium	2805300090	0.011	0.011	1.2E-04
Terbium	2846902040	0.002	0.001	2.4E-06
Terbium	2846902060	0.002	0.001	1.3E-06
Terbium	2846902084	0.002	0.001	1.4E-06
Terbium	2846908075	0.003	0.002	5.1E-06
Terbium	2846908090	0.001	0.001	1.0E-06
Terbium	8505110070	0.320	0.005	0.002

Mineral commodity	Trade code	Rare earth fraction	Elemental content	Overall elemental content
Thulium	2805300000	3.0E-04	3.0E-04	9.0E-08
Thulium	2805300050	0.003	0.003	1.1E-05
Thulium	2805300090	0.003	0.003	1.1E-05
Thulium	2846902040	0.001	4.4E-04	2.3E-07
Thulium	2846902060	0.001	2.2E-04	1.3E-07
Thulium	2846902084	0.001	3.0E-04	2.0E-07
Thulium	2846908075	0.001	4.8E-04	4.9E-07
Thulium	2846908090	3.0E-04	3.0E-04	9.0E-08
Ytterbium	2805300000	0.007	0.007	4.9E-05
Ytterbium	2805300050	0.076	0.076	0.006
Ytterbium	2805300090	0.076	0.076	0.006
Ytterbium	2846902040	0.012	0.010	1.2E-04
Ytterbium	2846902060	0.013	0.005	7.0E-05
Ytterbium	2846902084	0.014	0.007	9.1E-05
Ytterbium	2846908075	0.024	0.011	2.7E-04
Ytterbium	2846908090	0.007	0.007	4.9E-05
Yttrium	2805300000	0.021	0.021	4.4E-04
Yttrium	2805300050	0.227	0.227	0.052
Yttrium	2805300090	0.227	0.227	0.052
Yttrium	2846902015	1.000	0.787	0.787
Yttrium	2846902040	0.032	0.028	0.001
Yttrium	2846902060	0.026	0.010	2.7E-04
Yttrium	2846902082	1.000	0.293	0.293
Yttrium	2846902084	0.028	0.013	3.6E-04
Yttrium	2846904000	1.000	0.472	0.472
Yttrium	2846908075	0.050	0.023	0.001
Yttrium	2846908090	0.021	0.021	4.4E-04

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Appendix 3. Prices and price elasticities of supply and demand

Sources and assumptions for the prices for domestic production are noted below. Prices for domestic consumption were based on the combined value (quantity multiplied by price) of domestic production, the value of domestic net imports (as reported in the trade data) and, if applicable, the value of domestic releases from inventories, which were assumed to have the same unit value as those of domestic production. Where multiple prices are listed in the table below, the simple average was used unless otherwise specified. Where necessary, elemental contents, as reported in the table, were used to convert reported prices into their elemental content equivalents. All prices were the average for the year 2023. Weight-averaged unit values were estimated based on total trade value of the noted trade codes divided by total trade quantity (after adjusted for elemental content) for the year unless otherwise noted.

Table A3.1. Data sources for assumed prices for U.S. production in 2023.

Mineral commodity	Prices		
	Description	Assumed elemental content	References
Alumina	Weighted average U.S. import unit value of alumina (Harmonized Tariff Schedule of the United States, HTS, code 281820)	0.529	(U.S. Geological Survey, 2025a)
Aluminum	Average U.S. market (spot) price of aluminum ingot	1	(U.S. Geological Survey, 2025a)
Antimony	Average price of antimony metal, minimum 99.65%, Average price of antimony trioxide, minimum 99.8%	1 0.835	(U.S. Geological Survey, 2025a) (Argus Media Group, 2024)
Arsenic	Average metal, minimum 99% arsenic, at U.S. warehouses	1	(U.S. Geological Survey, 2025a)
Barite	Average unit value of ground barite	0.588	(U.S. Geological Survey, 2025a)
Bauxite	Weighted average U.S. import unit value of bauxite (HTS code 260600)	Variable by country	(Zen Innovations AG, 2025)
Beryllium	Weighted average U.S. import unit value of beryllium copper master alloy (HTS code 7405006030)	0.04	(Zen Innovations AG, 2025)
Bismuth	Annual average price of 99.99%-purity bismuth metal at warehouse (Rotterdam) in minimum lots of 1 metric ton.	1	(U.S. Geological Survey, 2025a)
Cadmium	Annual average free market price for 99.95% pure cadmium metal in 10-ton lots. Price includes cost, insurance, and freight at global ports.	1	(U.S. Geological Survey, 2025a)
Cerium	Annual average cerium oxide price	0.814	(Project Blue, 2025b)
Chromite	Annual average chromite ore (gross weight)	0.29	(U.S. Geological Survey, 2025a)
Chromium chemicals	Weighted average U.S. import unit value of sodium dichromate (HTS code 2841509100)	0.349	(Zen Innovations AG, 2025)
Chromium ferroalloys	Annual average ferrochrome price (adjusted for chrome content)	1	(U.S. Geological Survey, 2025a)
Chromium metal	Annual average chromium metal price	1	(U.S. Geological Survey, 2025a)
Cobalt	Annual average U.S. cobalt cathode spot price. Price was used for both cobalt metal and cobalt chemicals.	1	(U.S. Geological Survey, 2025a)
Copper, mined	Weighted average U.S. export unit value of copper ores and concentrates (HTS code 2603000010)	1	(Zen Innovations AG, 2025)

Mineral commodity	Prices		
	Description	Assumed elemental content	References
Copper, refined	U.S. producer price (Commodity Exchange + premium) of copper cathode	1	(U.S. Geological Survey, 2025a)
Dysprosium	Annual average dysprosium oxide price	0.871	(Project Blue, 2025b)
Erbium	Annual average erbium oxide price	0.875	(Project Blue, 2025b)
Europium	Annual average europium oxide price	0.864	(Project Blue, 2025b)
Feldspar	Annual average unit price for marketable feldspar	1	(U.S. Geological Survey, 2025a)
Fluorspar, acidspar	Annual average unit import value, including cost, insurance, and freight of acid-grade fluorspar (HTS code 2529220000)	0.477	(U.S. Geological Survey, 2025a)
Fluorspar, metspar	Annual average unit import value, including cost, insurance, and freight of metallurgical-grade fluorspar (HTS code 2529210000)	0.457	(U.S. Geological Survey, 2025a)
Gadolinium	Annual average gadolinium oxide price	0.868	(Project Blue, 2025b)
Gallium	Average unit value of U.S. high-purity, refined gallium imports	1	(U.S. Geological Survey, 2025a)
	Average unit value of U.S. low-purity, primary gallium imports	1	
Germanium	Average European price for minimum 99.999% purity for germanium metal	1	(U.S. Geological Survey, 2025a)
	Average European price for minimum 99.999% purity for germanium oxide	0.694	
Gold	Average Engelhard gold price quotation	1	(U.S. Geological Survey, 2025a)
Graphite, natural	Weighted average U.S. import unit value of flake graphite (HTS code 250410)	1	(Zen Innovations AG, 2025)
Graphite, synthetic	Annual average unit value of synthetic graphite production based on the ratio of domestic production value and quantity.	1	(U.S. Geological Survey, 2025b)
Hafnium	Average unwrought hafnium metal price	1	(U.S. Geological Survey, 2025a)
Helium	Weighted average U.S. export unit value of helium (HTS code 2804290010)	1	(U.S. Geological Survey, 2024)
Holmium	Annual average holmium oxide price	0.873	(Project Blue, 2025b)
Indium	Average price of indium, U.S. warehouses, free on board	1	(U.S. Geological Survey, 2025a)
Iridium	Average Engelhard unfabricated iridium metal price	1	(U.S. Geological Survey, 2025a)
Iron ore	Average unit value of iron ore reported at mines	0.631	(U.S. Geological Survey, 2025a)
Lanthanum	Annual average lanthanum oxide price	0.853	(Project Blue, 2025b)
Lead	Annual average North American price	1	(U.S. Geological Survey, 2025a)
Lithium	Annual average battery-grade lithium carbonate spot price	0.188	(Project Blue, 2025a)
Lutetium	Annual average lutetium oxide price	0.879	(Project Blue, 2025b)
Magnesium compounds	U.S. export unit value for caustic calcined magnesite (2519902000) and fused and dead-burned magnesia (HTS: 2519901000) weighted by the reported U.S. production capacity.	0.603	(Zen Innovations AG, 2025)

Mineral commodity	Prices		
	Description	Assumed elemental content	References
Magnesium metal	Annual average U.S. spot Western price for magnesium metal	1	(U.S. Geological Survey, 2025a)
Manganese alloys	Annual average price for high carbon ferromanganese; medium- and low-carbon ferromanganese; and silicomanganese, all free-on-board, North American warehouse	0.80 0.84 0.66	(Argus Media Group, 2024)
Manganese dioxide	Annual average manganese dioxide, minimum 91% alkaline battery grade, ex works, China	0.91	(Argus Media Group, 2024)
Manganese metal	Annual average price, manganese briquette, minimum 97% content, free-on-board, China	0.97	(Argus Media Group, 2024)
Manganese ore	Annual average price of metallurgical grade manganese ore, (adjusted for manganese content) including cost, insurance, and freight.	1	(U.S. Geological Survey, 2025a)
Manganese sulfate (high purity)	Annual average manganese sulfate price, minimum 32% manganese battery grade, ex works, China	0.32	(Argus Media Group, 2024)
Mica	Annual average scrap and flake mica price	1	(U.S. Geological Survey, 2025a)
Molybdenum	Annual average price of U.S. molybdic oxide price, reported in molybdenum content	1	(U.S. Geological Survey, 2025a)
Neodymium	Annual average neodymium oxide price	0.857	(Project Blue, 2025b)
Nickel, mined	Weighted average U.S. export unit value of nickel ores and concentrates (HTS code 2604000040)	1	(Zen Innovations AG, 2025)
Nickel, primary refined	Annual average London Metal Exchange cash price	1	(U.S. Geological Survey, 2025a)
Niobium	Average niobium (columbite) concentrate, minimum 50% Nb ₂ O ₅ content, cost including insurance and freight costs at main ports	0.699	(Argus Media Group, 2024)
Palladium	Average Engelhard unfabricated palladium metal price	1	(U.S. Geological Survey, 2025a)
Phosphates	Weighted average value of marketable phosphate rock, all-grades	0.122	(U.S. Geological Survey, 2025a)
Platinum	Average Engelhard unfabricated platinum metal price	1	(U.S. Geological Survey, 2025a)
Potash	Annual average free-on-board price of all potash products (muriate of potash; sulfate of potash; potassium magnesium sulfate), reported in dollars per metric ton of K ₂ O	0.830	(U.S. Geological Survey, 2025a)
Praseodymium	Annual average praseodymium oxide price	0.825	(Project Blue, 2025b)
Rhenium	Average annual price of 99.99% pure rhenium metal pellets	1	(U.S. Geological Survey, 2025a)
Rhodium	Average Engelhard unfabricated rhodium metal price	1	(U.S. Geological Survey, 2025a)
Ruthenium	Average Engelhard unfabricated ruthenium metal price	1	(U.S. Geological Survey, 2025a)
Samarium	Annual average samarium oxide price	0.862	(Project Blue, 2025b)
Selenium	Average price, minimum purity of 99.95% selenium, free on board, at U.S. warehouse	1	(U.S. Geological Survey, 2025a)
Silicon ferroalloys	Monthly average import unit value of ferrosilicon, 75% silicon, adjusted for silicon content	1	(U.S. Geological Survey, 2025a)

Mineral commodity	Prices		
	Description	Assumed elemental content	References
Silicon metal	Annual average of polysilicon price (9N purity), based on quarterly averages, and annual average metallurgical-grade silicon metal weighted by production of each product in the United States	1	(Project Blue, 2025c)
Silver	Average Engelhard's industrial bullion metal price	1	(U.S. Geological Survey, 2025a)
Strontium	Annual average U.S. import unit value of strontium carbonate (HTS 2836920000)	0.439	(Zen Innovations AG, 2025)
Tantalum	Average tantalite, basis 25%, Ta ₂ O ₅ content, cost including insurance and freight at main ports	0.819	(Argus Media Group, 2024)
Tellurium	Weighted average U.S. export unit value of tellurium (HTS code 2804500020)	1	(Zen Innovations AG, 2025)
Terbium	Annual average terbium oxide price	0.850	(Project Blue, 2025b)
Thulium	Annual average thulium oxide, minimum purity of 99%, price	0.876	(Ginger International Trade & Investment Pte. Ltd., 2025)
Tin	Annual average New York dealer price	1	(U.S. Geological Survey, 2025a)
Titanium ferroalloys	Annual average U.S. export unit value for ferrotitanium, (HTS code 7202910000)	0.70	(Zen Innovations AG, 2025)
Titanium metal	Annual average U.S. export unit value for wrought titanium, (HTS code 8108908000)	1	(Zen Innovations AG, 2025)
Titanium mineral concentrates	Annual average landed duty-paid unit value of U.S. imports for consumption of ilmenite	0.599	(U.S. Geological Survey, 2025a)
Titanium pigment	Annual average landed duty-paid unit value of U.S. imports for consumption of titanium pigment	0.599	(U.S. Geological Survey, 2025a)
Titanium sponge	Annual average titanium sponge price, ex works, China	1	(Project Blue, 2025d)
Tungsten	Average annual price of tungsten trioxide concentrates at Rotterdam warehouse	0.793	(U.S. Geological Survey, 2025a)
Vanadium	Ferrovandium, 78-82% vanadium content, Rotterdam Vanadium pentoxide fused flake, minimum 98% vanadium content, Rotterdam	0.800 0.549	(Argus Media Group, 2024)
Ytterbium	Annual average ytterbium oxide price	0.787	(Project Blue, 2025b)
Yttrium	Annual average yttrium oxide price	0.878	(Project Blue, 2025b)
Zinc, mined	Weighted average U.S. export unit value of zinc ores and concentrates (HTS code 2608000030)	1	(Zen Innovations AG, 2025)
Zinc, smelted	Annual average North American special high-grade zinc ingot based on London Metal Exchange price plus premium	1	(U.S. Geological Survey, 2025a)
Zirconium	Zircon unit value of landed-duty-paid U.S. imports for consumption from Australia, Senegal, and South Africa	0.481	(U.S. Geological Survey, 2025a)

Price elasticity estimates were obtained from Shojaeddini and others (2025). These elasticities represent the short-run elasticities unless otherwise noted.

Table A3.2. Summary of short-run price elasticity estimates used in the analysis

Mineral commodity	Short-run price elasticity of supply (PES)	Short-run price elasticity of demand (PED)	Notes
Alumina	0.66	-0.12	
Aluminum	0.14	-0.17	
Antimony	0.27	-0.12	
Arsenic	0.26	-0.03	
Barite	0.55	-0.38	
Bauxite	0.71	-0.23	
Beryllium	0.41	-0.39	
Bismuth	0.15	-0.14	
Cadmium	0.03	-0.07	
Cerium	0.14	-0.08	PES was based on refined production.
Chromite; Chromium chemicals; Chromium ferroalloys; Chromium metal	0.24	-0.40	PED was based U.S. demand. The same elasticities were used for chromite and all chromium forms
Cobalt	0.22	-0.17	Refined cobalt's PES was estimated based on mined cobalt's PES multiplied by the ratio refined copper to mined copper PES.
Copper, mined	0.08	-0.07	
Copper, refined	0.11	-0.07	
Dysprosium	0.13	-0.11	PES was based on refined production.
Erbium	0.37	-0.12	PES was based on refined production.
Europium	0.06	-0.29	PES was based on refined production.
Feldspar	0.63	-0.31	
Fluorspar	0.49	-0.30	Elasticities were applied to both fluorspar grades.
Gadolinium	0.15	-0.21	PES was based on refined production.
Gallium	0.40	-0.50	
Germanium	0.50	-0.29	
Gold	0.04	-0.19	
Graphite, natural	0.31	-0.38	
Graphite, synthetic	0.59	-0.45	Elasticities were based on static panel data.
Hafnium	0.18	-0.26	
Helium	0.58	-0.23	
Holmium	0.09	-0.06	PES was based on refined production.
Indium	0.30	-0.18	
Iridium	0.09	-0.24	
Iron ore	0.30	-0.11	
Lanthanum	0.21	-0.06	PES was based on refined production.
Lead	0.096	-0.05	PES was estimated based on the reported PES for lead mined multiplied by the ratio of PES for copper refined/copper mined.
Lithium	0.33	-0.11	PED was based on static assessment.
Lutetium	0.07	-0.08	PES was based on mined lutetium production.

Mineral commodity	Short-run price elasticity of supply (PES)	Short-run price elasticity of demand (PED)	Notes
Magnesium compounds	0.3	-0.31	
Magnesium metal	0.38	-0.23	
Manganese	0.46	-0.30	Elasticities were assumed to apply to all manganese forms.
Mica	0.28	-0.14	Elasticities were based on those of mica scrap and flake.
Molybdenum	0.14	-0.10	PED was based on static analysis.
Neodymium	0.18	-0.07	PES was based on refined production.
Nickel, mined	0.31	-0.09	PED was based on static analysis
Nickel, primary refined	0.43	-0.09	Refined nickel's PES was estimated based on mined nickel's PES multiplied by the ratio refined copper to mined copper PES.
Niobium	0.48	-0.48	
Palladium	0.28	-0.25	
Phosphates	0.07	-0.13	
Platinum	0.29	-0.47	
Potash	0.11	-0.35	
Praseodymium	0.15	-0.14	PES was based on refined production.
Rhenium	0.35	-0.45	
Rhodium	0.04	-0.09	
Ruthenium	0.11	-0.27	
Samarium	0.06	-0.29	PES was based on refined production.
Selenium	0.04	-0.06	
Silicon ferroalloys	0.28	-0.24	
Silicon metal	0.28	-0.18	
Silver	0.36	-0.40	Elasticities were based on static assessment.
Strontium	0.29	-0.38	
Tantalum	0.45	-0.31	
Tellurium	0.18	-0.09	Elasticities were based on static assessment.
Terbium	0.09	-0.18	PES was based on mined terbium production.
Thulium	0.53	-0.30	PES was based on refined production.
Tin	0.25	-0.07	
Titanium ferroalloys; Titanium metal; Titanium sponge	0.27	-0.60	Elasticities were based on static panel data.
Titanium mineral concentrates; Titanium pigment	0.16	-0.19	Elasticities were based on U.S. production and apparent consumption time-series data. Titanium mineral concentrates were assumed to have the same elasticities.
Tungsten	0.08	-0.08	
Vanadium	0.12	-0.17	
Ytterbium	0.06	-0.04	PES was based on refined production.
Yttrium	0.14	-0.06	PES was based on refined production.
Zinc	0.06	-0.12	Elasticities were based on zinc mine production but assumed to be applicable to both mined and smelted zinc.
Zirconium	0.24	-0.16	

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Appendix 4. Mineral commodity consumption by application and associated industry

For each mineral commodity analyzed, the quantity of the mineral commodity consumed in the United States was disaggregated by major application category. The data sources used and any assumptions made to determine the quantity of each mineral commodity's use by application category are noted in the following table. Each application category was linked to a U.S. Bureau of Economic Analysis (BEA) industry, which is also noted in the table along with the percent of each BEA industry's output that was estimated to have used the mineral commodity. The determination of how much of an industry's output was associated with a mineral commodity was predominantly determined based on data on the revenues generated from the sales of specific product(s) as defined by the North American Product Classification System (NAPCS) produced by the industry. The primary sources of data regarding the revenues by NAPCS product code were the 2017 Economic Census (U.S. Census Bureau, 2020) and the 2018-2021 Annual Survey of Manufacturers (U.S. Census Bureau, 2022). However, other sources and methods were used where necessary. The rare earth elements are reported in the following table as a single entry but were treated as 15 individual mineral commodities.

Table A4.1. Mineral commodity consumption by application and BEA industry. BEA = Bureau of Economic Analysis, NAPCS = North America Product Classification System.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
Alumina	Aluminum production	The percent of alumina used for aluminum production was obtained from the U.S. Geological Survey (2024). The remainder was split equally among the other applications.	Alumina refining and primary aluminum production [331313]	73.5	Assessment was based on the value of shipments of primary aluminum relative to the total output of this industry in 2023.
	Abrasives		Abrasive product manufacturing [327910]	8.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of aluminum oxide, nonmetallic sized grains, powders, and flour abrasives (including graded products only) [2027650000] in 2021 by this industry relative to its total output. The result was then multiplied by alumina's share of domestic alumina and bauxite consumption in this application.
	Ceramics and refractories		Clay product and refractory manufacturing [327100]	9.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fireclay, high alumina, and insulating brick and shapes [2041450003] in 2017 by this industry relative to its total output. The result was then multiplied by a

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					factor based on alumina's share of domestic alumina and bauxite consumption in this application.
	Chemicals		Other basic inorganic chemical manufacturing [325180]	2.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other inorganic aluminum compounds [2024550000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor based on alumina's share of domestic alumina and bauxite consumption in this application.
Aluminum	All applications	All aluminum consumption was connected to this industry, which includes the production of aluminum sheet, plate, foil, and the other aluminum products made from rolling, drawing, and extruding. In turn, this industry was connected to downstream industries through the economic input-output tables.	Aluminum production manufacturing from purchased aluminum [33131B]	97.9	The assessment was based on the value of aluminum products produced by this industry relative to its total output in 2021.
Antimony	Ammunition and ammunition primer	U.S. consumption of antimony by application were obtained from the U.S. Geological Survey (Klochko, 2024; U.S. Geological Survey, 2025a), some of which were withheld to avoid releasing company	Ammunition, arms, ordnance, and accessories manufacturing [33299A]	17.9	Antimony is used in small arms ammunition and ammunition primers. Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of primers (30 mm or less, 1.18 in. or less) and all other ammunition components [2008825000], Manufacturing of centerfire pistol cartridges, including cartridges interchangeable between rifles and pistols (30 mm or less, 1.18 in. or less) [2008775000], Manufacturing of shotgun shells

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		proprietary information but used in this analysis. Reported consumption quantities were extrapolated to apparent consumption quantities based on imports of antimony oxide and metal and secondary antimonial lead production for each application that consumed antimony in this form.			[2008800000], and Manufacturing of centerfire pistol cartridges, including cartridges interchangeable between rifles and pistols (30 mm or less, 1.18 in. or less) [2008775000] in 2021 by this industry relative to its total output.
	Ceramics		Other fabricated metal manufacturing [332999]	4.2	Antimony trioxide is used as an opacifier in ceramics, mainly in lead-free porcelain enamels for cast iron and steel plumbing fixtures. Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of enameled iron and metal sanitary ware and components, including baths, showers (receptors, stalls), sinks, wash basins, and lavatories (toilets, portable chemical toilets, urinals, flush tanks) [2038425000] in 2021 by this industry relative to its total output.
	Glass	Antimony's use (as antimonial lead) in lead-acid batteries was excluded because that use is largely self-sufficient from closed-loop recycling.	Glass and glass product manufacturing [327200]	0.04	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other Basic Inorganic Chemical Manufacturing [325180] industry, which produced antimony oxide (except pigments).
	Pigments		Synthetic dye and pigment manufacturing [325130]	2.8	Antimony trioxide is used as a white pigment (Pigment White 11). Antimony is also used in several other inorganic pigments: nickel antimony titanate, Pigment Yellow 53 (Chemical Abstracts Service [CAS] Number, 8007-18-9), chrome antimony titanate, Pigment Brown 24 (CAS number, 68186-90-3), manganese antimony titanate, Pigment Yellow 164 (CAS number: 68412-38-4), and manganese chrome antimony brown, Pigment Brown 40 (CAS number 68412-38-4) (Filella and others, 2020). These products likely fall under the NAPCS

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					Manufacturing of other white opaque pigments [2024300000] and Manufacturing of white extender pigments (including barytes, blanc fixe, and whiting), ceramic color pigments, and all other inorganic pigments [2024400000]. The percent of Synthetic dye and pigment manufacturing [325130] industry that uses antimony was approximated based on revenues for these NAPCS codes, as well as information the U.S. Environmental Protection Agency (2022) and 2002 Economic Census (U.S. Census Bureau, 2004a), which contains more detailed product level data.
	Plastics		Plastics material and resin manufacturing [325211]	14.4	Antimony is used a stabilizer in polyvinyl chloride and as a catalyst in the production of polyethylene terephthalate (PET). Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of thermoplastic resins and plastics materials, polyvinyl chloride [2025350012] and Manufacturing of thermoplastic resins and plastics materials, polyester [2025350015] in 2017 relative to the industry's total output. Given that over 95% of polyethylene terephthalate produced worldwide was catalyzed with antimony trioxide (Sivaram, 2016), with the remaining being germanium oxide in Japan, it was assumed that 100% of these products required antimony.
	Flame retardant: plastics		Plastics material and resin manufacturing [325211]	1.0	Antimony trioxide is used with halogenated (brominated and chlorinated) flame retardants as a synergist additive (Mathys and others, 2007). Halogenated flame retardants reportedly comprise 30-36% of the global market of flame retardants in recent years (European Chemical Agency, 2023;

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					Mordor Intelligence, 2021a). The U.S. flame retardant thermoplastic market size in 2022 was estimated at \$3.4 billion (Grand View Research, 2022c). One-third of this value was assumed to use antimony flame retardants. The resultant value was divided by the revenue generated by this industry.
	Flame retardant: rubber		Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	2.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other Basic Inorganic Chemical Manufacturing [325180] industry, which produced antimony oxide (except pigments).
	Flame retardant: adhesives		Adhesive manufacturing [325520]	1.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other Basic Inorganic Chemical Manufacturing [325180] industry, which produced antimony oxide (except pigments).
	Flame retardant: textile		Fabric mills [313200]	5.6	The U.S. flame retardant textile market was estimated at approximately \$2.2 billion in 2023 (Global Industry Analysts Inc., 2024). One-third of this value was assumed to use antimony flame retardants. The resultant value was divided by the revenue generated by this industry.
	Flame retardant: paper		Paper mills [322120]	0.03	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other coated and processed papers, excluding for packaging uses [2023500000] in 2021 by this industry relative to its total output. One-third of this value was assumed to use antimony flame retardant.
	Other metallic applications		Nonferrous metal (except copper and aluminum) rolling,	1.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
			drawing, extruding and alloying [331490]		all goods and services from the Nonferrous Metal (except Aluminum) Smelting and Refining [331410] industry, which produced antimony metal.
Arsenic	Herbicides and insecticides	The use of arsenic in the United States was split into applications based on data from the U.S. Geological Survey (2024).	Pesticide and other agricultural chemical manufacturing [325320]	0.4	Assessment was based on the quantity of arsenic estimated to go this application, which is assumed to be all for monosodium methanearsonate (with an assumed 46.5% arsenic content), multiplied by a price of \$127.24 per 2.5-gallon jug that contains 6 pounds of monosodium methanearsonate per gallon (P&M Solutions LLC, 2025) and divided by the total output of this industry.
	Wood preservation	The "Herbicides and insecticides" and the "Wood preservation" were separated based on data from the Chemical Data Reporting (U.S. Environmental Protection Agency, 2022). The undifferentiated "other" application was split equally into sub-applications due to lack of data.	Sawmills and wood preservation [321100]	3.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of wood poles, piles, and posts, treated [2035600000], Treating wood owned by others with arsenical chemicals, creosote, and other chemicals (including fire-retardant and pentachlorophenol) [2052125000], Manufacturing of railway crossties, mine ties, switch ties, and bridge ties, treated [2035550000], Manufacturing of plywood and sawn wood fence pickets, paling, and rails, treated [2035625000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 42%. This factor represents the approximate percent of wood utility poles that were treated with arsenic (Beyond Pesticides, 2003).
	Semiconductors	Arsenic's use in other applications, such as ammunition and pigments, were assumed to be negligible.	Semiconductor and related device manufacturing [334413]	1.9	Assessment was based on the value of gallium arsenide semiconductor products in the United States (Grand View Research, 2024f) as a percent of the entire industry's output in 2023.
	Metallurgy		Copper rolling, drawing, extruding and alloying [331420]	0.005	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Batteries, lead-acid		Storage battery manufacturing [335911]	4.2	Assessment was based on based on the ratio of the quantity of arsenic used in lead-acid batteries, divided by an assumed average arsenic content of lead alloys of 0.125%, to the quantity of lead used in lead-acid batteries in the United States in 2023.
	Other: clay products		Clay product and refractory manufacturing [327100]	0.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of glazed brick and other brick (paving, floor, and sewer) [2035800000], Manufacturing of clay floor and wall tile, glazed and unglazed (including ceramic mosaic tile) [2036000000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 1%. This factor was an assumption given that declining use of arsenic.
	Other: optical lenses		Optical instrument and lens manufacturing [333314]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of all other miscellaneous optical instruments and lenses (including binoculars and astronomical instruments) [2018600000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 1%. This factor was an assumption given that declining use of arsenic.
	Other: pharmaceuticals		Pharmaceutical preparation manufacturing [325412]	0.01	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other pharmaceutical preparations affecting neoplasms, the endocrine system, and metabolic diseases, for human use [2010150031] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 0.13%. Arsenic trioxide is used to treat acute promyelocytic leukemia, which

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					comprises 10-15% of all acute myeloid leukemia (Leukemia & Lymphoma Society, 2025) that comprise 1% of all cancers (National Cancer Institute, 2024).
Barite	Oil and gas well drilling	The proportions of barite's use by application in the United States were obtained from the U.S. Geological Survey (2025b), which were withheld to avoid releasing company proprietary information but used in this analysis.	Drilling oil and gas wells [213111]	75.8	Assessment was based on the value of shipments of the following NAPCS code: Drilling oil and gas wells, including drilling in, spudding in, or tailing in [1001625000] in 2017 by this industry relative to its total output.
	Plastics		Plastics material and resin manufacturing [325211]	7.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Paints		Paint and coating manufacturing [325510]	3.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Barium chemicals		Other basic inorganic chemical manufacturing [325180]	0.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Rubber		Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	0.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
Bauxite	Alumina production	The percent of bauxite used for alumina production was obtained	Alumina refining and primary aluminum production [331313]	14.4	Assessment was based on the value of alumina production as percent of this industry's output in 2023.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Abrasives	from the U.S. Geological Survey (2025b). The use of bauxite in other applications was aggregated by the reference to avoid disclosing company propriety information but was used in this analysis.	Abrasive product manufacturing [327910]	0.01	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of aluminum oxide, nonmetallic sized grains, powders, and flour abrasives (including graded products only) [2027650000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor based on bauxite's share of domestic alumina and bauxite consumption in this application.
	Chemicals		Other basic inorganic chemical manufacturing [325180]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other inorganic aluminum compounds [2024550000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor based on bauxite's share of domestic alumina and bauxite consumption in this application.
	Refractory		Clay product and refractory manufacturing [327100]	4.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fireclay, high alumina, and insulating brick and shapes [2041450003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor based on bauxite's share of domestic alumina and bauxite consumption in this application.
Beryllium	Aerospace and defense: aerospace	<p>The proportions of beryllium's use by application was obtained from Mordor Intelligence (2024a).</p> <p>The healthcare and "other" application category were combined due to overlap uses.</p>	Aircraft manufacturing [336411]	44.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of manned military aircraft, including manned aircraft for U.S. military and any other manned aircraft built to military specifications [2012100003], Manufacturing of unmanned robotic military aircraft, including unmanned aircraft for U.S. military and any other unmanned aircraft built to military specifications [2012100006], Manufacturing of manned civilian aircraft [2012125003] in 2017 by this industry relative to its total output. The result was then multiplied by a

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		Beryllium's use in the reported application categories were disaggregated into sub-applications based on the value of each associated industry's output that uses beryllium as a percent of the output of all industries associated with beryllium within the application category. This approach was taken for all application categories except for the oil and gas and other energy category, which was split equally among the sub-applications.			factor of 50%, which was the assumed share of the products that use beryllium.
	Aerospace and defense: communication		Broadcast and wireless communications equipment [334220]	5.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of space-based (satellite) stations [2011825003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 80%, which was the assumed share of the products that use beryllium.
	Aerospace and defense: search and detection		Search, detection, and navigation instruments manufacturing [334511]	14.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of search, detection, and acquisition radar systems and equipment, airborne and missile/space [2017500009], Manufacturing of airborne navigational systems, inertial navigation systems [2017500057], Manufacturing of missile-borne and space vehicle guidance systems [2017500042], Manufacturing of other search, detection, identification, and tracking systems and equipment [2017500031] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 80%, which was the assumed share of the products that use beryllium.
	Analytical equipment		Analytical laboratory instrument manufacturing [334516]	1.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of analytical and scientific instruments, excluding optical [2017725000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 1.4%. This factor represents the value of the products [3345160121 and 3345160143] that use X-ray tubes or windows as a percent of the total value of this NAPCS code in 2004 (U.S. Census Bureau, 2004c).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Automotive		Motor vehicle electrical and electronic equipment manufacturing [336320]	2.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Copper rolling, drawing, extruding and alloying [331420] industry.
	Electronics and telecommunication: connectors and switches		Other electronic component manufacturing [33441A]	1.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of electronic connectors, including parts [2033800000], Manufacturing of switches, mechanical, for electronic circuitry [2033875000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 10%, which was the assumed share of the products that use beryllium.
	Electronics and telecommunication: current carrying wire		Wiring device manufacturing [335930]	0.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of current-carrying wiring devices, metal contacts, precious and other [2039300009], Manufacturing of current-carrying wiring devices, pin and sleeve connectors [2039300012], Manufacturing of pressure connectors [2039500003], Manufacturing of compression connectors [2039500006] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 10%, which was the assumed share of the products that use beryllium.
	Electronics and telecommunication: relays		Relay and industrial control manufacturing [335314]	1.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of relays for electronic circuitry, industrial control overload, and switchgear-type [2033950000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 10%, which was the assumed share of the products that use beryllium.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Industrial components		Plastics material and resin manufacturing [325211]	21.5	Assessment was based on the percent of plastics manufactured with beryllium-based injection molds. An estimated 43% of global plastics were manufactured using injection molding (Grand View Research, 2022f), of which an estimated 50% of molds in the U.S. contain beryllium (Knudson, 2017).
	Lasers		Electromedical and electrotherapeutic apparatus manufacturing [334510]	1.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of medical laser equipment [2018000031] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 62.7%. This factor represent the percent of lasers assumed to use beryllium active materials (Parkhi, 2020).
	Oil and gas and other energy: nuclear		Electric power generation, transmission, and distribution [221100]	0.3	Beryllium is usually used as a neutron source for new nuclear reactors (World Nuclear Association, 2025a). Assessment was based on the value of shipments of the following NAICS industry: Nuclear electric power generation [221113] in 2017 relative to its total output. The result was then multiplied by a factor of 1.1%, which represented the nameplate capacity of the sole new nuclear power plant that was commission in 2023 as a percent of all nuclear power plants operating in the United States in 2023 (U.S. Energy Information Administration, 2025).
	Oil and gas and other energy: tools for energy		Drilling oil and gas wells [213111]	41.0	Beryllium is used in non-sparking tools for oil and gas well drilling. Copper-based alloys (excluding brass and bronze), many of which use beryllium, represented 41% of the non-sparking tools market (Market.Us, 2024b)
	X-ray tubes and windows		Irradiation apparatus manufacturing [334517]	51.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of irradiation (ionizing radiation) equipment, including X-ray, beta ray, gamma ray, and nuclear [2018025000]

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					in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 57.9%, which represents the proportion of the NAPCS codes that likely uses beryllium X-ray tubes and windows based on the value sum of the more detailed NAPCS codes: Manufacturing of digital radiography equipment, used for diagnostic purposes [2018025003]; Manufacturing of computerized axial tomography (CT or CAT scan), used for diagnostic purposes [2018025006]; Manufacturing of all other medical diagnostic X-ray equipment, including dental and conventional [2018025009]; Manufacturing of industrial and scientific X-ray equipment [2018025015]; and Manufacturing of X-ray tubes [2018025018]
Bismuth	Pharmaceuticals	<p>The percent of bismuth used by application was obtained from Mordor Intelligence (2025a).</p> <p>Bismuth consumed in the metallurgical applications were disaggregated based on data provided to the U.S. Geological Survey (2025b), which were withheld to avoid releasing company proprietary information but used in this analysis.</p>	Pharmaceutical preparation manufacturing [325412]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of antacids and antidiarrheals, including acid neutralizing and products with coating functions [2010250006] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 57%. This factor represents, Pepto-Bismol's share of liquid/powder stomach remedies sales in the United States in 2019 (Petruzzi, 2024).
	Metallurgical: malleable iron and steel		Iron and steel mills and ferroalloy manufacturing [331110]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Metallurgical: aluminum alloys		Secondary smelting and alloying of aluminum [331314]	0.05	Assessment was based on the value of bismuth consumed in this application divided by an assumed bismuth content in aluminum alloys of 0.64%

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		Bismuth consumed in the electronics and semiconductor applications was disaggregated based on the value of the industry's output that was estimated to have used bismuth.			(MatWeb, 2025), divided by the total quantity of secondary aluminum produced in the United States (U.S. Geological Survey, 2025a).
	Metallurgical: fusible alloys		Other general purpose machinery manufacturing [33399A]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of automatic fire sprinklers [2040000000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 20%, which was the assumed market share of fire sprinklers that use bismuth.
	Electronics and semiconductors: electronic solder		Printed circuit assembly (electronic assembly) manufacturing [334418]	2.0	The market share of bismuth-based solders was reported to range from 1-3% (Indium Corp, 2010).
	Electronics and semiconductors: thermoelectric devices		Semiconductor and related device manufacturing [334413]	0.1	In 2023, the value of the global thermoelectric devices market was \$502 million (Maximize Market Research, 2024), which represented approximately 0.1% of the global semiconductor devices market (Semiconductor Industry Association, 2024).
	Cosmetics and personal care		Toilet preparation manufacturing [325620]	0.03	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of cosmetics [2010675003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 0.08%. This factor represents the sales value of eye cosmetics and blushers as a percent of total cosmetics in the United States in 2002 (U.S. Census Bureau, 2004a) multiplied by an estimated share for bismuth, which was based on the global sales of cosmetic-grade bismuth oxychloride (Business Research Insights, 2025a) as a percent of the value of all mineral cosmetics (Grand View Research, 2023f).
	Other: pigments and paints		Paint and coating manufacturing [325510]	3.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of paints,

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					traffic marking, all types, including shelf goods and highway department [2040350009], Manufacturing of paints and enamels, automotive, other transportation and machinery refinishing, including primers [2040350012] in 2017 by this industry relative to its total output.
Cadmium	Batteries, rechargeable	The proportions of cadmium's use by application in the United States were obtained from Mordor Intelligence (2025b). The undifferentiated "other" application was assumed to be for solar photovoltaics.	Storage battery manufacturing [335911]	0.9	Cadmium is used in nickel-cadmium rechargeable batteries. To estimate the value of these products, the value of U.S. manufacturing of lithium-ion battery cells and lead acid batteries were subtracted from the total industry output of the storage battery manufacturing industry [335911] in 2023. The value of lithium-ion battery cells manufactured in the United States was based on production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a) relative to the total output of this industry. The value of lead-acid battery manufacturing was based on sum of the sale revenues from the following NAPCS codes, averaged for years 2021 and 2020: Manufacturing of storage batteries, lead-acid-type, BCI dimensional size group 8D (1.5 cu ft (.042 cu m) and smaller) [2030050000], Manufacturing of motive-power-type lead acid storage batteries, larger than BCI dimensional size group 8D (1.5 cu ft (.042 cu m)), including mining and industrial locomotive [2030075000], Manufacturing of all other lead acid storage batteries, larger than BCI dimensional size group 8D (1.6 cu ft (.042 cu m)), including communication and standby emergency [2030100000]. The result was then multiplied by 16%, which represents nickel-cadmium battery sales' global share among share of all other storage battery (excluding lead-acid and lithium-ion

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					batteries) based on data from Mordor Intelligence (2022a).
	Coatings and electroplating		Coating, engraving, heat treating and allied activities [332800]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Pigments		Synthetic dye and pigment manufacturing [325130]	1.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of white extender pigments (including barytes, blanc fixe, and whiting), ceramic color pigments, and all other inorganic pigments [2024375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 8.7%, which represents the global value of cadmium pigments as a percent of all other inorganic pigments excluding titanium dioxide, iron oxide, and chromium (Global Market Insights, 2024a)
	Alloys		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	0.05	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Other (solar photovoltaics)		Semiconductor and related device manufacturing [334413]	1.5	Assessment was based on the quantity of thin-film solar photovoltaics produced in the United States in 2023 less the estimated amount that was copper-indium-gallium-(di)selenide solar cells multiplied by the average U.S. solar photovoltaics module value in 2023 (Feldman and others, 2024) divided by the total industry output.

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Chromite	Chemicals	All domestic consumption of chromite ores and concentrates was assumed to be used to produce chromium chemicals.	Other basic inorganic chemical manufacturing [325180]	3.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Iron, gold, silver, and other metal ore mining [2122A0] industry.
Chromium chemicals	Pigments	Chromium chemicals' uses were split equally among these applications.	Synthetic dye and pigment manufacturing [325130]	3.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of chrome colors [2024325000] in 2021 by this industry relative to its total output.
	Plating		Coating, engraving, heat treating and allied activities [332800]	4.9	Assessment was based on the value of shipments of the following NAPCS code: Electroplating, plating, polishing, anodizing, and coloring [2053500000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 20%, which represented the percent of global electroplating market that was based on chromium (Global Growth Insights, 2025a).
	Petrochemical catalysts		Plastics material and resin manufacturing [325211]	2.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Chromium ferroalloys	Steels	The proportions of ferrochromium's use by application in the United States were estimated based on the trade data and data from the U.S. Geological Survey (2025b).	Iron and steel mills and ferroalloy manufacturing [331110]	8.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of stainless steel ingots and semifinished shapes and forms [2026890000], Manufacturing of hot rolled stainless steel, finished, sheet and strip [2026920000], Manufacturing of cold rolled stainless steel, finished product, sheet and strip [2026935000], Manufacturing of hot rolled stainless steel bars, plates, and structural shapes [2026970000] in 2021 by this industry relative to its total output.

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	Cast iron		Ferrous metal foundries [331510]	17.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of gray iron castings for rolling mill, construction, utility, automotive, and all other uses [2027925000] in 2018 by this industry relative to its total output.
Chromium metal	Superalloys: aerospace	The proportions of chromium metal's use by application in the United States were estimated based on the trade data and data from the U.S. Geological Survey (2025b). Chromium metal's use in superalloys was disaggregated among the various sub-applications based on data from the Eckard (2017).	Aircraft engine and engine parts manufacturing [336412]	86.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output.
	Superalloys: industrial turbines		Turbine and turbine generator set units manufacturing [333611]	57.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output.
	Superalloys: industrial processes		Metal tank (heavy gauge) manufacturing [332420]	3.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of nonferrous metal process pressure vessels, tanks, and kettles for refineries, chemical plants, paper mills (more than 24 in. outside diameter and not less than 5 cu ft cap.), custom fabricated at the factory [2016350003] in 2017 by this industry relative to its total output.

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	Superalloys: oil and gas		Mining and oil and gas field machinery manufacturing [333130]	44.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of rotary oil and gas field drilling machinery and equipment, excluding parts [2013050000], Manufacturing of other oil and gas field drilling machinery and equipment, excluding parts [2013075000], Manufacturing of oil and gas field production machinery and equipment (excluding pumps and parts) [2013100000], Manufacturing of oil and gas field derricks, substructures and accessories, including well-surveying machinery and equipment and well-logging equipment [2013150000] in 2021 by this industry relative to its total output.
	Superalloys: automotive		Other motor vehicle parts manufacturing [336390]	3.3	Assessment was based on the value of the North American turbocharger market (Global Market Insights, 2025a) divided by the total industry output in 2023.
	Other alloys		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	1.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
Cobalt chemicals	Batteries, lithium-ion	Domestic cobalt use in batteries was separated from the reported chemicals and ceramics application category based on information from Benchmark Minerals Intelligence Ltd. regarding U.S. lithium-	Storage battery manufacturing [335911]	44.8	Assessment was based on the value of lithium-ion battery cells manufactured in the United States that contain cobalt, which was based production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a) relative to the total output of this industry in 2023.
	Other: agriculture		Other animal food manufacturing [311119]	0.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

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		ion battery cathode active material			all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: catalysts	production (Benchmark Mineral Intelligence Ltd., 2023b). Cobalt's use in all other application was split based on global data for cobalt uses (Project Blue, 2025a).	Petroleum refineries [324110]	37.5	Assessment was based on the charge capacity of catalytic hydrotreating in the United States in 2023 as a percent of atmospheric crude oil distillation capacity (U.S. Energy Information Administration, 2024b) multiplied by 42%, which represents that approximate share of cobalt-based catalysts used in hydrodesulfurization (Strategy & Stats Insider, 2022).
	Other: ceramics		Clay product and refractory manufacturing [327100]	20.27	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: chemicals		Other basic inorganic chemical manufacturing [325180]	0.02	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: glass		Glass and glass product manufacturing [327200]	0.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: paint		Paint and coating manufacturing [325510]	5.52	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: pigments		Synthetic dye and pigment manufacturing [325130]	2.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

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					all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: tires		Tire manufacturing [326210]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Cobalt metal	Cemented carbides: Cutting tool, machine tool accessories, and industrial molds	The use of cobalt by application was obtained from the U.S. Geological Survey (2025b). Steels and other alloys were disaggregated between steels, magnetic alloys and other alloys based on data reported to the U.S. Geological Survey that were aggregated to avoid disclosing company proprietary data. Cobalt's use in cemented carbides was split between two industries based on the reported consumption of	Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	45.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of cutting tools (including broaches, reamers, hobs) and all other miscellaneous solid and tipped carbide cutting tools for machine tools and metalworking machinery, excluding tips and blanks [2050000000], Manufacturing of high-speed steel end and solid and tipped carbide end mills, non- and indexable-inserted-blade-type, throwaway-insert-type, and all other miscellaneous milling cutters [2050025000], Manufacturing of carbon and high-speed steel shank and solid and tipped carbide twist drills, including masonry twist drill bits, gun drills, combined drills, countersinks, and counterbores [2050075000], Manufacturing of taps (excluding taps in threading sets and screw plates and inserted chaser types) and precision ground carbide indexable and throwaway inserts for machine tools and metalworking machinery [2050100000] in 2018 by this industry relative to its total output.
	Cemented carbides: special dies and tools	tungsten carbide by those two industries in the 2012 Economic Census (U.S. Census Bureau, 2012b).	Special tool, die, jig, and fixture manufacturing [333514]	46.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of metalworking die and die sets [2016200000], Manufacturing of punches, die parts, and other special tooling [2016225000] in 2021 by this industry relative to its total output.

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	Steels	<p>Cobalt's use in superalloys was split into two applications based on data from on nickel- and cobalt-based superalloys reported by Eckard (2017), excluding superalloys used in nuclear reactors, industrial processes, oil and gas, and automotive.</p> <p>In addition to the consumption of cobalt to manufacture permanent magnets, the United States also imported rare earth permanent magnets that containing cobalt. The consumption was allocated using the same approach described for rare earth elements in this table.</p>	Iron and steel mills and ferroalloy manufacturing [331110]	0.03	Assessment was based on the value of cobalt-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of cobalt-containing steel produced, the quantity of cobalt consumed in various types of steel was divided by estimated elemental contents of cobalt-containing steels (Roskill Information Services Ltd., 2019a) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).
	Superalloys: aerospace		Aircraft engine and engine parts manufacturing [336412]	84.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 97%, the percent of superalloys that were estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
	Superalloys: industrial turbines		Turbine and turbine generator set units manufacturing [333611]	52.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a

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					factor of 91%, the percent of superalloys that was estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
	Magnetic alloys		Other fabricated metal manufacturing [332999]	1.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of permanent magnets, excluding ceramic permanent magnets [2034200000] in 2021 by this industry relative to its total output.
	Alloys (other)		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	0.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Magnets, neodymium-iron-boron: Power steering		Motor vehicle steering, suspension component (except spring), and brake systems manufacturing [3363A0]	11.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other motor vehicle steering and suspension components, including motor vehicle ball joints [2042675000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 55%. This factor represents the approximate share of motor vehicle steering that use rare earth permanent magnets (Stanford Magnets, 2024).
	Magnets, neodymium-iron-boron: Automotive electronics		Audio and video equipment manufacturing [334300]	4.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of speakers for automobiles [2032400000] in 2021 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: Consumer electronics, hard disk drives		Computer storage device manufacturing [334112]	17.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of disk subsystems and disk arrays for multiuser computer systems [2011625003] and Manufacturing of disk drives (all sizes) [2011625006] in 2017 by this industry relative to its total output.

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	Magnets, neodymium-iron-boron: Consumer electronics, other		Audio and video equipment manufacturing [334300]	39.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of speakers, including loudspeaker systems and loudspeakers [2008625000] and Manufacturing of other consumer audio and video equipment, including audio and video recorders and players (camcorders) [2008650000] in 2021 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: Robotics		Other general purpose machinery manufacturing [33399A]	9.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of industrial robots [2016650000] in 2021 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: light duty truck and utility vehicle electric motors		Light truck and utility vehicle manufacturing [336112]	19.1	Assessment was based on the percent of light truck and utility vehicles manufactured in the United States that were battery electric, hybrid or plug-in hybrid vehicles in 2023 (U.S. Environmental Protection Agency, 2024).
	Magnets, neodymium-iron-boron: automobile electric motors		Automobile manufacturing [336111]	31.2	Assessment was based on the percent of automobiles in the United States that were battery electric, hybrid or plug-in hybrid vehicles in 2023 (U.S. Environmental Protection Agency, 2024).
	Magnets, neodymium-iron-boron: Other electric motors		Motor and generator manufacturing [335312]	9.5	Assessment was based on the assumption that 10% of motors and generators used rare earth permanent magnets, 95% of which were based on neodymium-iron-boron magnets.
	Magnets, neodymium-iron-boron: Energy saving		Air conditioning, refrigeration, and warm air heating equipment manufacturing [333415]	6.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of room air conditioners and dehumidifiers, excluding portable dehumidifiers [2007325000] and Manufacturing of unitary air conditioners, excluding air source heat pumps [2038825000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 23%. This factor

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					represents the share of all air conditioner units that use neodymium-iron boron magnets (Roskill Information Services Ltd., 2020a).
	Magnets, neodymium-iron-boron: Other, medical		Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of magnetic resonance imaging equipment (MRI) [2018000003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 14%, which represents the share of low-field strength MRI global market share in 2024 (Grand View Research, 2025b) multiplied by an assumed 95% market share for neodymium-iron-boron magnets.
	Magnets, neodymium-iron-boron: Other, guided missiles		Guided missile and space vehicle manufacturing [336414]	52.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of complete guided missiles [2012400000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 75%, which was the assumed market share of neodymium-iron-boron magnets.
	Magnets, neodymium-iron-boron: Other, search, detection, and navigation instruments		Search, detection, and navigation instruments manufacturing [334511]	5.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electronic warfare countermeasures equipment (jamming, communications, and radar) [2017500033], Manufacturing of gyroscopes [2017475012], Manufacturing of acceleration indicators, rate-of-climb and angle-of-attack indicators, and artificial horizon flight instruments [2017475006], Manufacturing of airborne navigational systems, inertial navigation systems [2017500057], Manufacturing of search, detection, and acquisition radar systems and equipment, airborne and missile/space [2017500009],

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					Manufacturing of other search, detection, and acquisition radar systems and equipment [2017500012], Manufacturing of tracking radar systems and equipment (fire control, bombing, bombing-navigational radar, aircraft and missile tracking radar, etc.) [2017500015], Manufacturing of sonar search, detection, tracking, and communication systems and equipment guidance, including ASM (sonar telephone, depth finding, hydrophones mapping, sonobuoys, etc.) [2017500021] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 25%, which was the assumed market share of neodymium-iron-boron magnets.
	Magnets, samarium-cobalt: Motors and generators		Motor and generator manufacturing [335312]	0.5	Assessment assumed that 10% of motors and generators used rare earth permanent magnets, 5% of which were based on samarium-cobalt magnets.
	Magnets, samarium-cobalt: Guided missiles		Guided missile and space vehicle manufacturing [336414]	17.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of complete guided missiles [2012400000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 25%, which was the assumed share for samarium-cobalt magnets.
	Magnets, samarium-cobalt: medical		Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.05	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of magnetic resonance imaging equipment (MRI) [2018000003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 0.75%. which represents the share of low-field strength MRI global market share in 2024 (Grand View Research, 2025b), multiplied by an assumed 5% market share for samarium-cobalt magnets.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Magnets, samarium-cobalt: Search, detection, and navigation instruments		Search, detection, and navigation instruments manufacturing [334511]	17.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electronic warfare countermeasures equipment (jamming, communications, and radar) [2017500033], Manufacturing of gyroscopes [2017475012], Manufacturing of acceleration indicators, rate-of-climb and angle-of-attack indicators, and artificial horizon flight instruments [2017475006], Manufacturing of airborne navigational systems, inertial navigation systems [2017500057], Manufacturing of search, detection, and acquisition radar systems and equipment, airborne and missile/space [2017500009], Manufacturing of other search, detection, and acquisition radar systems and equipment [2017500012], Manufacturing of tracking radar systems and equipment (fire control, bombing, bombing-navigational radar, aircraft and missile tracking radar, etc.) [2017500015], Manufacturing of sonar search, detection, tracking, and communication systems and equipment guidance, including ASM (sonar telephone, depth finding, hydrophones mapping, sonobuoys, etc.) [2017500021] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 75%, which was the assumed market share of samarium-cobalt magnets.
Copper, mined	All applications	All mined copper consumption domestically was connected to this industry, which was connected to	Nonferrous metal (except aluminum) smelting and refining [331410]	32.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of refined primary copper and copper-base alloy and primary copper smelter products, not commercial grade, produced for further refining, including blister or anode copper, cathode, wire bar, ingot and ingot bar,

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		downstream industries through the input-output tables.			cakes, slabs, shot, etc. [2027175000] in 2021 by this industry relative to its total output.
Copper, refined	All applications	All refined copper consumed domestically was connected this industry, which was connected to downstream industries through the input-output tables.	Copper rolling, drawing, extruding and alloying [331420]	95.9	Assessment was based on the total shipments of this industry in 2021 less the value of shipments from products that were identified as non-copper relative to the total output of this industry.
Feldspar	Glass	The proportions of feldspars use by application were obtained from the U.S. Geological Survey (2025a). Feldspar's use in ceramics was split from its use as a filler in paints and coatings based on information from SCRREEN (2023)	Glass and glass product manufacturing [327200]	54.0	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of glass containers (including value of packaging) [2048450000], Manufacturing of flat glass (float, sheet, and plate process) [2026050000], Manufacturing of specialized glass for windows and doors [2037275000], Manufacturing of other glass fiber, textile-type (including yarn, strand, staple yarn, sliver, roving, chopped strand, and milled glass fiber) [2020575000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 95%, which is the assumed share of glass that requires feldspar (SCRREEN, 2023)
	Ceramics		Clay product and refractory manufacturing [327100]	34.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of clay floor and wall tile, glazed and unglazed (including ceramic mosaic tile) [2036000000], Manufacturing of all wet and dry process voltage porcelain products and components, including steatite electrical products and other ceramic electrical products and components for electronic applications [2034100000], Manufacturing of vitreous china,

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					porcelain, and earthenware (semivitreous) table and kitchenware (including household, hotel, or commercial uses) (including bone and feldspar) [2007400000], Manufacturing of vitreous plumbing fixtures, vitreous china lavatories, and flush tanks, including all other plumbing accessories and earthenware [2038400000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 95%, which is the assumed share of glass that requires feldspar (SCREEN, 2023)
	Paints and coatings		Paint and coating manufacturing [325510]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Ground or treated mineral and earth manufacturing [327992] industry.
Fluorspar, acidspar	Aluminum production	The proportions of acid-grade fluorspar use by application in the United States was estimated based on global consumption fractions (Project Blue, 2025b).	Alumina refining and primary aluminum production [331313]	70.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of aluminum ingot, including billet [2026995000] in 2021 by this industry relative to its total output.
	Fluorocarbons		Industrial gas manufacturing [325120]	10.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fluorocarbon gases [2024225000] in 2021 by this industry relative to its total output.
	Fluoropolymers	The other chemicals application category was split equally into various downstream applications.	Plastics material and resin manufacturing [325211]	4.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other chemicals: glass		Glass and glass product manufacturing [327200]	2.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other chemicals: Lithium-ion batteries		Storage battery manufacturing [335911]	44.8	Assessment was based on the value of lithium-ion battery cells manufactured in the United States that contain cobalt, which was based on production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a) relative to the total output of this industry in 2023.
	Other chemicals: metal processing		Coating, engraving, heat treating and allied activities [332800]	17.9	Assessment was based on the value of shipments of the following NAPCS code: Heat treating of metal for the trade (heat treating, pickling, annealing, brazing, shot peening, tempering, etc.) [2053450000] in 2021 by this industry relative to its total output.
	Other chemicals: nuclear fuel (uranium hexafluoride)		Electric power generation, transmission, and distribution [221100]	1.6	Fluorspar is used for the conversion of uranium oxide to uranium hexafluoride. Although the sole operating domestic producer that performs this conversion is likely in the Other basic inorganic chemical manufacturing [325180] industry, the use is connected to the final using industry (nuclear electric power generation). Assessment was based on the value of shipments of the following NAICS industry: Nuclear electric power generation [221113] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 4.65%, which represents the fraction of domestically produced uranium purchased by owners and operators of U.S. civilian nuclear power reactors in 2023 (U.S. Energy Information Administration, 2024c).
	Other chemicals: petroleum alkylation		Petroleum refineries [324110]	42	Assessment was based on the percent of U.S. petroleum refining capacity that uses alkylation (American Fuel & Petrochemical Manufacturers and American Petroleum Institute, 2023).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Other chemicals: semiconductor manufacturing		Semiconductor and related device manufacturing [334413]	93.5	High-purity, electronic grade, hydrofluoric acid and fluorogases are used extensively in semiconductor device manufacturing processes (for example, etching). Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of microprocessors [2033575000], Manufacturing of memory [2033600000], Manufacturing of other integrated circuit packages [2033625000], Manufacturing of other semiconductor devices, including semiconductor parts such as chips, wafers, and heat sinks [2033700000] in 2018 by this industry relative to its total output.
	Other chemicals: water fluoridation		Water, sewage and other systems [221300]	67.7	Assessment was based on the value of shipments of the following NAPCS code: Water supply, transmission, treatment, and distribution, including water supply through irrigation systems [6000175003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 72.3%, which represents the percent of the U.S. population served with fluorinated water (U.S. Centers for Disease Control and Prevention, 2024).
Fluorspar, metspar	Cement	The proportions of metallurgical-grade fluorspar's use by application in the United States was estimated based on global consumption fractions (Project Blue, 2025b), with the glass and ceramics category being split into equal proportions.	Cement manufacturing [327310]	1.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Ceramics		Clay product and refractory manufacturing [327100]	0.02	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Glass		Glass and glass product manufacturing [327200]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Iron and steel		Iron and steel mills and ferroalloy manufacturing [331110]	2.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
Gallium	Semiconductor devices	All domestic gallium consumption was connected to this industry, which was connected to downstream industries through the input-output tables.	Semiconductor and related device manufacturing [334413]	7	Assessment was based on the "base case" described in detail by Nassar and others (2024),
Germanium	Fiber optics	Application fractions were based on the analysis conducted by Nassar and others (2024), with the exception that use in the fiber optics was merged into a single BEA industry.	Communication and energy wire and cable manufacturing [335920]	25.0	Assessment was based on the "base case" described in detail by Nassar and others (2024), except for semiconductor devices and solar cells which was updated based the value of germanium-based U.S. semiconductor devices sales (Grand View Research, 2024e) relative to that industry's output in 2023.
	Infrared optics: night-vision equipment		Optical instrument and lens manufacturing [333314]	2.4	
	Infrared optics: infrared surveillance devices		Search, detection, and navigation instruments manufacturing [334511]	6.9	
	Semiconductor devices and solar cells		Semiconductor and related device manufacturing [334413]	1.8	
	Radiation detection devices		Watch, clock, and other measuring and controlling device manufacturing [33451A]	0.7	

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	Medical devices		Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.4	
Gold	Jewelry	<p>The proportions of U.S. gold consumption was first disaggregated into major categories based on data for North American gold consumption in 2022 (Kirilenko, 2023).</p> <p>The proportion of gold's use the electrical & electronics application was split based the expenditure of the associated BEA industries on gold and other precious metals (Material code: 33141911) reported in 2012 Economic Census (U.S. Census Bureau, 2012a).</p> <p>The proportion of gold's use in the dental application was split proportionally based of the value of shipments of the Manufacturing of</p>	Jewelry and silverware manufacturing [339910]	50.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of jewelry and personal goods (excluding costume), gold and platinum (excluding gold and platinum clad or plated to silver and nonprecious metals) [2005600000], Manufacturing of other jewelers' findings and materials, including gold, platinum, and silver plated to nonprecious metal [2034400000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 96%, which represents the value of gold consumed by U.S. jewelry manufacturing relative to that of U.S. consumption of gold and platinum in jewelry manufacturing.
	Electrical & electronics: other electronic components		Other electronic component manufacturing [33441A]	52	Assessment was based on the percent of global printed circuit board finishes that used gold in 2016 (Shah, 2018).
	Electrical & electronics: semiconductor and related devices		Semiconductor and related device manufacturing [334413]	30	This factor approximates the percent of semiconductors that use gold based on gold's market share of bonding wire in 2023 (~23%) (KBV Research, 2024a) and, additionally, the share of industry output that is based on gallium-based compound semiconductors (~7%, (Nassar and others, 2024) where gold is used for contact metallization.
	Electrical & electronics: printed circuit assemblies		Printed circuit assembly (electronic assembly) manufacturing [334418]	52	Assessment was based on the percent of global printed circuit board finishes that used gold in 2016 (Shah, 2018).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Dental equipment and supplies	dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] NAPCS code reported by those two associated BEA industries.	Dental equipment and supplies manufacturing [339114]	4.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 51.5%. This factor represents the approximate market share of dental metals that were based on gold dental alloys in 2022 (KBV Research, 2024b).
	Dental laboratories	The proportion of gold's use in the other application was split equally due to lack of additional information. Gold's use in official coins and other investment instruments was not connected to any BEA industry.	Dental laboratories [339116]	0.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 51.5%. This factor represents the approximate market share of dental metals that were based on gold dental alloys in 2022 (KBV Research, 2024b).
	Other: watches		Watch, clock, and other measuring and controlling device manufacturing [33451A]	0.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of watches (excluding watch bands and batteries) [2005575000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 8%. This factor represents the approximate market share of ultra-luxury market for watches (Amed and others, 2021; Grand View Research, 2023h).
	Other: plating		Coating, engraving, heat treating and allied activities [332800]	3.7	Assessment was based on the value of shipments of the following NAPCS code: Electroplating, plating, polishing, anodizing, and coloring [2053500000] in 2021 by this industry relative to its total output. The

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					result was then multiplied by a factor of 15%, which represented the percent of global electroplating market that was based on gold (Global Growth Insights, 2025a).
Graphite, natural	All applications	All domestic natural graphite consumption was connected to this industry, which was connected to downstream industries through the input-output tables.	Carbon and graphite product manufacturing [335991]	12.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of graphite electrodes for electric furnaces and electrolytic cell use [2026775000] and Manufacturing of all other carbon and graphite products, including carbon and graphite fibers, brushes, brush plates, contacts, excluding refractories [2026800000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 14.5%. This factor represents the natural graphite share of the combined calculated apparent consumption value of natural and synthetic graphite.
Graphite, synthetic	All applications	All domestic synthetic graphite consumption was connected to this industry, which was connected to downstream industries through the input-output tables.	Carbon and graphite product manufacturing [335991]	74.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of graphite electrodes for electric furnaces and electrolytic cell use [2026775000] and Manufacturing of all other carbon and graphite products, including carbon and graphite fibers, brushes, brush plates, contacts, excluding refractories [2026800000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 85.5%. This factor represents the synthetic graphite share of the combined calculated apparent consumption value of natural and synthetic graphite.
Hafnium	Superalloys: aerospace	Hafnium's use in the United States by application was based on data reported by	Aircraft engine and engine parts manufacturing [336412]	71.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines

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		Mordor Intelligence (2024b). Hafnium's use in superalloys was split based on the split for cobalt in superalloys, with the "other superalloy use" being allocated to space applications.			[2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 82.56%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: industrial gas turbines	Hafnium's use in the undifferentiated "other" applications was split equally between catalysts and semiconductors (Alkane Resources Ltd., 2017).	Turbine and turbine generator set units manufacturing [333611]	39.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 69.11%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: rocket nozzles		Propulsion units and parts for space vehicles and guided missiles [33641A]	10	Hafnium is added as an alloying agent (for example, in the C103 alloy) for use in rocket nozzles. An assumed 10% market share was assumed given that no specific data were found.
	Optical coatings		Optical instrument and lens manufacturing [333314]	0.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of sighting, tracking, and fire-control equipment, optical-type [2018575000], Manufacturing of night vision goggles and equipment [2018575012], Manufacturing of binoculars and astronomical instruments [2018600003], Manufacturing of optical

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					test and inspection equipment [2018600006] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 1% given that hafnium likely comprises a small market share in these applications.
	Nuclear		Electric power generation, transmission, and distribution [221100]	0.4	Assessment was based on the value of nuclear electricity generation relative to the value of all electricity generation in 2017 multiplied by hafnium's market share in nuclear control rods, which was estimated at 1.5%. This estimate was based on the ratio of hafnium to silver-indium-cadmium required per kilowatt-hour in nuclear power plants (Nuclear Energy Agency, 2011) multiplied by the share of nuclear electricity generation that was on pressurized water reactors (where silver-indium-cadmium control rods are used) in the United States in 2023 (World Nuclear Association, 2025b).
	Plasma cutting		Other general purpose machinery manufacturing [33399A]	0.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other welding equipment, components, and accessories (excluding arc, resistance, and gas welding equipment) [2014850000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 5.7%, which was the share of other welding equipment that used plasma welding in 2002 (U.S. Census Bureau, 2004a), multiplied by an assumed market share of 10% for hafnium.
	Other: semiconductors		Semiconductor and related device manufacturing [334413]	38.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of microprocessors [2033575000] in 2018 by this industry relative to its total output. Hafnium has been used as high dielectric constant material since the introduction of 45 nanometer technology.

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	Other: catalysts		Plastics material and resin manufacturing [325211]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of thermoplastic resins and plastics materials, polyethylene [2025350003], Manufacturing of thermoplastic resins and plastics materials, polypropylene [2025350006] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 1% given that hafnium-based catalysts likely produced a small share of polyolefins.
Helium	Analytical and science laboratory applications	The proportions of helium's use in the United States in 2023 by application were obtained from the U.S. Geological Survey (2024). The share of helium's use in analytical, engineering, lab, science, and specialty gases was split between analytical and science laboratory applications and engineering applications based on data reported by the U.S. Geological Survey (2020a). Helium's use in semiconductor applications was split	Scientific research and development services [541700]	46.1	Assessment was based on the value of shipments of the following NAPCS codes: Basic and applied research in natural and exact sciences, including biological sciences [7009675000] and Basic and applied research in medical and health sciences [7009750000] in 2017 by this industry relative to its total output.
	Engineering applications		Scientific research and development services [541700]	29.3	Assessment was based on the value of shipments of the following NAPCS code: Basic and applied research in engineering and technology [7009700000] in 2017 by this industry relative to its total output.
	Semiconductor devices		Semiconductor and related device manufacturing [334413]	14.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other integrated circuit packages [2033625000] in 2017 by this industry relative to its total output.
	Fiber optics		Communication and energy wire and cable manufacturing [335920]	25.0	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of fiber optic cable, for all other applications [2039175000] and Manufacturing of fiber optic cable, for communications applications [2039150000] in 2021 by this industry relative to its total output.
	Lifting gas: weather services		All other miscellaneous professional, scientific,	1.4	Assessment was based on the value of shipments of the following NAPCS code: Weather forecasting

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		from its use in fiber optic applications based on data reported by the U.S. Geological Survey (2020a) for semiconductors applications, with the remainder being allocated to fiber optic applications.	and technical services [5419A0]		services [7012263000] in 2017 by this industry relative to its total output.
	Lifting gas: party-balloons	Helium's use in welding, which was assumed to be mainly for aerospace and automotive applications, was split equally between these two uses.	All other retail [4B0000]	0.3	Assessment was based the value of helium-filled balloon industry in the United States relative to this industry's total output. The value of helium-filled balloon industry was estimated by multiplying the value of the global helium-filled party balloon market in 2022 (\$2.5 billion) by 1.07, which accounts for the annualized growth rate of that market, to estimate the value in 2023 (Verified Market Reports, 2025h). The result was then multiplied by 35%, which is the estimated market share for United States, based on a reported market share of 38% for North America (Verified Market Reports, 2025h).
	Leak detection	Helium's use in lifting gas applications was split between weather services and party-balloons based on data from the National Research Council (2010), which provides an estimate for helium's use in weather balloons per year. Helium's use in party-balloons was assumed to constitute the remainder of the	Aircraft manufacturing [336411]	82.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft, including all aircraft for U.S. military and any other aircraft built to military specifications [2012100000] and Manufacturing of civilian aircraft [2012125000] in 2021 by this industry relative to its total output.
	Magnetic resonance imaging		Medical and diagnostic laboratories [621500]	10.0	Assessment was based on the value of shipments of the following NAPCS code: Magnetic resonance imaging (MRI) [7004160015] in 2017 by this industry relative to its total output.
	Aerospace propulsion units		Propulsion units and parts for space vehicles and guided missiles [33641A]	9.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of missile and space vehicle engine and propulsion parts and accessories [2012525000] in 2018 by this industry relative to its total output.
	Welding: aerospace		Aircraft engine and engine parts manufacturing [336412]	70.0	Assessment assumed that all aircraft engine and engine parts required welding. Helium is widely used in arc welding, in various proportions. However, it is

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		lifting gas application fraction. Helium's use in the undifferentiated "other" applications was assumed to be for pharmaceuticals, automotive air bags, and hard disk drive. The application fraction was split equally among these three uses.			mostly used in gas metal arc welding. Gas metal arc welding is about twice as common as gas tungsten arc welding. While argon is more commonly used in gas tungsten arc welding, helium can be used in some applications. A factor of 70% was thus assumed.
	Welding: automotive		Motor vehicle body manufacturing [336211]	70.0	Assessment assumed that all motor vehicle bodies required welding. Helium is widely used in arc welding, in various proportions. However, it is mostly used in gas metal arc welding. Gas metal arc welding is about twice as common as gas tungsten arc welding. While argon is more commonly used in gas tungsten arc welding, helium can be used in some applications. A factor of 70% was thus assumed.
	Diving gas		Sporting and athletic goods manufacturing [339920]	0.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of sailboards, surfboards, water skis, and underwater sports equipment (excluding cameras and watches) [2009050009] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 43.9%. This factor represents the percent of this NAPCS code's revenues that in 2002 that were specific to underwater equipment based on the 2002 Economic Census (U.S. Census Bureau, 2004a).
	Pharmaceuticals		Hospitals [622000]	0.02	Assessment was based on the value of the Heliox market in North America for medical use in 2024, (Wise Guy Reports, 2025) which was estimated to be half of the total use of Heliox, relative to the output of this BEA industry in 2023.
	Automobile air bags		Other motor vehicle parts manufacturing [336390]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of motor vehicle air bag assemblies and parts, new

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					[2032425000] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 7.8%, which represents the approximate share helium's use in motor vehicle air bags. Specifically, helium is particularly used in curtain airbags for fast deployment. The 2024 value of the global curtain airbag market was \$4.52 billion (Grand View Research, 2024a), while the overall airbag market that year, according to Precedence Research, was \$58.18 billion (Precedence Research, 2024).
	Hard drives		Computer storage device manufacturing [334112]	1.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of disk subsystems and disk arrays for multiuser computer systems [2011625003] and Manufacturing of disk drives (all sizes) [2011625006] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 7%. This factor estimates that there were approximately 18 million helium-filled hard disk drives shipped each year (1 million per month for one company (Shendar, 2021) that had reportedly two-thirds of all helium-filled hard disk drive shipments (Western Digital, 2022)) out of 260 million hard disk drives per year in 2020-2021 (Statista, 2024).
Indium	Indium tin oxide: electronic displays	Application fractions were based on data for indium's consumption by application for year 2021 for all countries except China (Beijing Antaika Information Development	Other electronic component manufacturing [33441A]	8.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of all other specialized electronic hardware [2033925018] in 2017 by this industry relative to its total output.
	Indium tin oxide: coated glass		Glass and glass product manufacturing [327200]	0.5	Assessment was based on the value of the U.S. indium-tin-oxide coated glass market (Fact.MR, 2025) as a percent of this industry's output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Semiconductor compounds (including, indium phosphide, aluminum gallium indium phosphide, and copper indium gallium (di)selenide)	Co. Ltd., 2020). Indium tin oxide use was split between electronic displays and coated glass based information reported by the U.S. Geological Survey (Jorgenson and George, 2005).	Semiconductor and related device manufacturing [334413]	7.3	Assessment was based on U.S. market in 2023 for "other" semiconductor devices as reported by Grand View Research (2024f), which includes Indium phosphide, silicon germanium, aluminum gallium indium phosphide, cadmium telluride, copper indium gallium selenide, and mercury cadmium telluride compounds. The value for silicon germanium was removed based on data from Grand View Research (2024e) reported on germanium semiconductor devices in the United States.
	Solders and alloys: electronics	Solders and alloys were split equally between electronics and fusible alloys. The undifferentiated "other" application was assumed to be for dental alloys.	Printed circuit assembly (electronic assembly) manufacturing [334418]	1.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Solders and alloys: fusible alloys		Other general purpose machinery manufacturing [33399A]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of automatic fire sprinklers [2040000000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 20%, which was the assumed market share of fire sprinklers that use indium.
	Other: dental alloys		Dental equipment and supplies manufacturing [339114]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
Iridium	Chemical: acetic acid synthesis	The proportions of iridium's use by application were obtained from Cowley (2024). These data pertain to global application fractions but were assumed applicable to the United States.	Other basic organic chemical manufacturing [325190]	0.3	Assessment was based on an estimated production capacity of iridium-based U.S. acetic acid production capacity (~600 thousand metric tons) (ICIS, 2019) and a unit value for acetic acid of \$740 per metric ton (average price in North America in June 2023) (ChemAnalyst, 2024a) relative to the industry's total output in 2023.
	Chemical: Pesticide synthesis		Pesticide and other agricultural chemical manufacturing [325320]	5.8	Assessment was based on the quantity of S-Metolachlor used in the United States (U.S. Department of Agriculture National Agricultural Statistics Service, 2024) multiplied by the price of this herbicide (FBN, 2024) by this industry relative to its total output in 2021.
	Electronics: crucibles to grow single crystals of metal oxides	The proportion of iridium's in the "chemical" application was split equally among the associated BEA industries.	Other electronic component manufacturing [33441A]	5.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of crystals, filters, piezoelectric, and other related electronic devices (excluding microwave filters) [2033825000] in 2021 by this industry relative to its total output.
	Electrochemical: chlor-alkali	The proportion of iridium's use in the "electrochemical" application was split among the associated BEA industries based on additional information noted by Cowley (2024).	Other Basic Inorganic Chemical Manufacturing [325180]	6.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of chlorine, compressed or liquefied [2024625000] and Manufacturing of sodium hydroxide (caustic soda) [2024650000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 50.8%. This factor represents that approximate share of U.S. chlorine production in 2022 that used membrane cells (Kreuz and others, 2022), which use iridium-coated electrodes.
	Electrochemical: treatment of ballast water	The proportion of iridium's use in the undifferentiated "other" application was split among the associated BEA industries based on	Ship building and repairing [336611]	1.6	Assessment was based on the value of the global market for ballast water treatment systems in 2022, (Maximize Market Research, 2023a) multiplied by the North American share of that market (55%),

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		additional information presented by Heraeus Precious Metals, and SFA (Oxford) Ltd. (2021).			(Maximize Market Research, 2023a), an assumed 80% share of the North American market for the United States, and a 37% share ballast water treatment systems for the ruthenium-iridium based electrolytic chlorination systems. The result was divided by the total output of the industry in 2022 (Heraeus Precious Metals and SFA (Oxford) Ltd., 2020).
	Electrochemical: copper foil for printed circuit boards		Other electronic component manufacturing [33441A]	12.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of bare printed circuit boards [2014930000] in 2021 by this industry relative to its total output.
	Electrochemical: copper foil for batteries		Storage battery manufacturing [335911]	12.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of storage batteries (excluding lead acid) [2030125000] in 2019 by this industry relative to its total output.
	Electrochemical: proton exchange membrane		Industrial gas manufacturing [325120]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of argon and hydrogen [2024200000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 1.05%. This factor accounts for the share of this NAPCS code that was for the manufacture of hydrogen (roughly 73%, (U.S. Census Bureau, 2004d)), the percent of hydrogen produced by electrolyzers (roughly 7%) (U.S. Energy Information Administration, 2024a), and the percent of electrolyzers that were based on proton membrane exchange (roughly 20%) (Hydrogen Council and McKinsey & Company, 2023).
	Other applications: automotive spark plugs		Motor vehicle electrical and electronic equipment manufacturing [336320]	0.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of spark plugs (all types) [2029575000] in 2021 relative to the industry's total output. The result was then multiplied

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					by a factor of 32%. This factor represents the approximate percent of spark plugs that use iridium (Fortune Business Insights, 2024).
	Other applications: aerospace		Aircraft engine and engine parts manufacturing [336412]	4.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of parts and accessories for civilian aircraft engines [2029475000], Manufacturing of parts and accessories for military aircraft engines [2029450000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 10%. This factor represents the share of aircraft engines spark plugs that use iridium (AviationPros, 2007).
	Other applications: biomedical devices		Electromedical and electrotherapeutic apparatus manufacturing [334510]	6.9	Assessment was based on based on the sum of the U.S. market of pacemakers (Grand View Research, 2022d) and cochlear implants (Grand View Research, 2023a) and value of shipments from Manufacturing of defibrillators [2018000024], the latter which was multiplied by 59% to approximate the share of defibrillators that were implantable (The Brainy Insights, 2023), relative to the output of the industry in 2021.
	Other: jewelry		Jewelry and silverware manufacturing [339910]	0.1	Assessment was based on the value of the calculated apparent consumption of this commodity by this industry in 2023 multiplied by the ratio of revenue generated by this industry to the total material expenditure of this industry in 2017 based on from data reported in the Economic Census (U.S. Census Bureau, 2023), relative to the total output of this industry in 2023.
Iron ore	Steels	Domestic consumption of iron ore for steel production represented	Iron and steel mills and ferroalloy manufacturing [331110]	31.6	Assessment was based on domestic production of pig iron and direct-reduced iron multiplied by 92% (to approximate iron content) as a percent of domestic

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		98% of total domestic iron ore consumption (U.S. Geological Survey, 2025a). The remaining 2% was divided equally among the remaining non-steel applications.			raw steel production in 2023 (U.S. Geological Survey, 2025a).
	Catalysts for ammonia production		Fertilizer manufacturing [325310]	6.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of synthetic ammonia for fertilizer use [2034625006] and Manufacturing of anhydrous synthetic ammonia for other uses [2034625009] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 95%. as it represents the approximate percent of ammonia produced using catalysts (Smith and Torrente-Murciano, 2021).
	Cement clinker		Cement manufacturing [327310]	1.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of Portland cement and other Portland hydraulic cements (including oil well, white cement, blended cements, etc.), and masonry cement and cement clinker [2026400000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 1%, which was the assumed percent of cement that used iron ore as an additive.
	Ferrite magnets		Other fabricated metal manufacturing [332999]	1.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of permanent magnets, excluding ceramic permanent magnets [2034200000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 87.39%. as it represents the approximate percent of revenue from permanent magnets that were ferrite magnets using projected 2022 North American market data as a proxy (Kumar, 2017).
	Oil and gas well drilling		All other chemical product and preparation manufacturing [3259A0]	0.05	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of drilling mud materials (mud thinners, thickeners, and

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					purifiers) [2041350006] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 1%. as it represents the approximate percent of oil and gas well drilling that use iron ore given that the market is currently dominated by barite (Latunussa and others, 2020)
	Paints and pigments		Synthetic dye and pigment manufacturing [325130]	2.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of iron oxide pigments [2024350000] in 2021 by this industry relative to its total output.
Lead	Ammunition	The proportions of lead's use by application in the United States were obtained from the U.S. Geological Survey (2025b), some of which were aggregated to avoid releasing company proprietary information but used in this analysis at the most disaggregated level available. The undifferentiated "other" application category was assumed to be lead's use as a polyvinyl chloride stabilizer.	Ammunition, arms, ordnance, and accessories manufacturing [33299A]	95	Assessment was based on a reported statistics that states that 95% of ammunition in the United States contains lead (Gorman, 2017).
	Batteries, lead-acid		Storage battery manufacturing [335911]	49.2	Assessment was based on the average value of shipments of the following NAPCS codes: Manufacturing of storage batteries, lead-acid-type, BCI dimensional size group 8D (1.5 cu ft (.042 cu m) and smaller) [2030050000], Manufacturing of motive-power-type lead acid storage batteries, larger than BCI dimensional size group 8D (1.5 cu ft (.042 cu m)), including mining and industrial locomotive [2030075000], Manufacturing of all other lead acid storage batteries, larger than BCI dimensional size group 8D (1.6 cu ft (.042 cu m)), including communication and standby emergency [2030125000] in 2020 and 2021 relative to the total industry output in 2023.
	Bearings: Motor Vehicles		Motor vehicle transmission and power train parts manufacturing [336350]	0.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal

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					(except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Bearings: Other transportation equipment		Railroad rolling stock manufacturing [336500]	3.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of passenger and freight train cars, rebuilt [2012200003] in 2017 by this industry relative to its total output.
	Leaded brass pipe fittings		Valve and fittings other than plumbing [33291A]	1.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of metal fittings, flanges, and unions for piping systems (iron, copper, copper alloy brass and bronze) [2038300000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 15.4%. This factor represents the approximate share of brasses that contain lead, which was estimated based on the quantity of lead used in brass mills in the United States in 2023 divided by an assumed lead-content of brass of 1.5% divided by the total output of brass mills in the United States in 2023 (Copper Development Association Inc., 2024).
	Cable coverings		Communication and energy wire and cable manufacturing [335920]	2.7	Assessment was based on the value of the U.S. lead sheathed cable market relative (Verified Market Reports, 2024) to the overall output of this industry in 2023.
	Caulking lead		Adhesive manufacturing [325520]	2.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nonstructural caulking compounds and sealants [2040425000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 10%, which represents an approximate share for lead. In the global caulk and sealants market, 90% of the market share is for silicone

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					sealants, acrylic latex caulks, hybrid polymer caulks, and mildew-free sealants (Verified Market Reports, 2025d). Lead is not used in any of these types, so it was assumed to be within the 10% of other caulks and sealants.
	Casting metal: electrical machinery		Material handling equipment manufacturing [333920]	5.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of work trucks, forklifts, and tractors fitted or not fitted with lifting and handling equipment, self-propelled, electric, gasoline, and other power system [2015625000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 44%, which represents the share this output that was based on forklifts as reported in the Economic Census (U.S. Census Bureau, 2004a).
	Casting metal: motor vehicles		Other motor vehicle parts manufacturing [336390]	18.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of miscellaneous motor vehicle parts and components [2042975000] in 2021 by this industry relative to its total output.
	Casting metals: ships		Ship building and repairing [336611]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Casting metals: nuclear radiation shielding		Plate work and fabricated structural product manufacturing [332310]	0.02	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of fabricated steel plate shielding for use in nuclear reactor buildings [2017175000] in 2018 by this industry relative to its total output.
	Extruded metal for construction		Hardware manufacturing [332500]	2.1	Assessment was based on the estimated expenditures of this industry on this mineral

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					commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Extruded metal for tanks, process vessels		Metal tank (heavy gauge) manufacturing [332420]	1.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Sheet metal: construction		Ornamental and architectural metal products manufacturing [332320]	2.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Sheet metal: storage tanks		Metal tank (heavy gauge) manufacturing [332420]	3.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nonferrous metal process pressure vessels, tanks, and kettles for refineries, chemical plants, paper mills (more than 24 in. outside diameter and not less than 5 cu ft cap.), custom fabricated at the factory [2016350003] in 2017 by this industry relative to its total output.
	Sheet metal: medical radiation shielding		Surgical appliance and supplies manufacturing [339113]	0.8	Assessment was based on the value of lead-based medical radiation shielding market in North America as a percent of this industry's output in 2023 (Grand View Research, 2023e).
	Solder: construction		Ornamental and architectural metal products manufacturing [332320]	0.05	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal

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					(except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Solder: metal cans		Metal can, box, and other metal container (light gauge) manufacturing [332430]	2.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Solder: electrical and electronics		Printed circuit assembly (electronic assembly) manufacturing [334418]	39.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of printed circuit assemblies, loaded boards and modules (printed circuit boards with inserted electronic components) [2041925000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 42.6%, which represents the approximate share of lead-based solders (Global Market Insights, 2024c).
	Solder: motor vehicles		Motor vehicle electrical and electronic equipment manufacturing [336320]	2.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of motor vehicle instrument board assemblies and all other electrical and electronic components, new [2030025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 42.6%, which represents the approximate share of lead-based solders (Global Market Insights, 2024c).
	Terne metal		Iron and steel mills and ferroalloy manufacturing [331110]	0.1	Assessment was based on the quantity of lead consumed in this application divided by an assumed lead content of 67%, which was then divided by the total steel output of the United States in 2023 (U.S. Geological Survey, 2025a).
	Collapsible tubes		Other fabricated metal manufacturing [332999]	0.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of

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					fabricated metal collapsible tubes, aluminum and all other metals, including tin, tin-coated, tin-lead alloy, and lead [2048625000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 25%, which was the approximate share of lead-based collapsible tubes (Anand and Mane, 2014).
	Paints		Paint and coating manufacturing [325510]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Glass and ceramics		Glass and glass product manufacturing [327200]	1.4	Assessment was based on the value of leaded glass windows in North America relative to this industry's output in 2023 (Wise Guy Reports, 2024a).
	Pigments and chemicals		All other chemical product and preparation manufacturing [3259A0]	0.06	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of rubber processing preparations, including red lead and 2-mercaptoimidazoline rubber accelerator composition [2025775000] in 2018 by this industry relative to its total output.
	Other: polyvinyl chloride stabilizer		Plastics material and resin manufacturing [325211]	4.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of thermoplastic resins and plastics materials, polyvinyl chloride [2025350012] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 44.9%, which represent the percent of polyvinyl chloride stabilizers based on lead (Coherent Market Insights, 2025).
Lithium	Air conditioning	The quantity of lithium consumed in the United States for rechargeable batteries was based on	Air conditioning, refrigeration, and warm air heating equipment manufacturing [333415]	0.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other heat transfer equipment, including room air-induction units, mechanical refrigeration systems used on all

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		the quantity of lithium that would have been required for U.S. cathode production (with an assumed lithium content of ranging from 7.1% to 7.2% depending on cathode type) and the U.S. battery cell production by cathode type (with lithium content varying by cathode type (Olivetti and others, 2017)) as reported by Benchmark Mineral Intelligence Ltd. (2023b; 2023c).			types of vehicles, and absorption refrigeration and dehydration systems [2017800108] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 45.7%, which represents the percent of the global market value of absorption chillers that were based on lithium bromide (Maximize Market Research, 2025a).
	Aluminum alloys	The remaining proportions of lithium's use in the United States were estimated based on data provided by Project Blue (2025c) and Miatto and others (2020). The undifferentiated "other" application was split evenly among paints, electronics, and other inorganic chemicals.	Secondary smelting and alloying of aluminum [331314]	1.5	Assessment was based on quantity of lithium consumption in this application divided by an assumed average lithium content of aluminum-lithium alloys (2%) multiplied by an assumed price of \$10/kg divided by the total output of this industry. Lithium may have also been used in the production of aluminum using a subset Söderberg method, but the quantities produced using this method that required lithium were believed to be negligible in 2023 (Roskill Information Services Ltd., 2020b).
	Batteries, lithium-ion		Storage battery manufacturing [335911]	45.1	Assessment was based on the value of lithium-ion battery cells manufactured in the United States, which was based production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a) relative to the total output of this industry in 2023.
	Batteries, primary		Primary battery manufacturing [335912]	31.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of primary batteries, excluding lead acid [2010950000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 33.1%, which represented the approximate percent of global primary battery that used lithium (Market.U.S., 2025b) in 2024.
	Ceramics		Clay product and refractory manufacturing [327100]	2.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of vitreous china, porcelain, and earthenware

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					(semivitreous) table and kitchenware (including household, hotel, or commercial uses) (including bone and feldspar) [2007400000], Manufacturing of stoneware table and kitchen articles, household and commercial (for serving, cooking, preparing, and storing food and drink) [2007425000] in 2021 by this industry relative to its total output.
	Glass		Glass and glass product manufacturing [327200]	2.2	Assessment was based on the quantity of lithium consumed in this application multiplied by the price of spodumene (Project Blue, 2025c) relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry
	Glass-ceramics		Major household appliance manufacturing [335220]	4.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electric (including microwave) household ranges, ovens, surface cooking units, and equipment, excluding parts and accessories [2007100000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 28.1%, which represents the percent of U.S. electric and induction cooktops that were based on induction (which were believed to be the main use of lithium in this application) (Grand View Research, 2023b).
	Lubricating greases		Other petroleum and coal products manufacturing [324190]	22.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of petroleum lubricating oils and greases [2041950000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 60.92%. the percent of grease products that use lithium (conventional or complex) in North American in 2023 (Grease Technology Solutions LLC, 2023).

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	Pharmaceuticals		Pharmaceutical preparation manufacturing [325412]	0.04	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other psychotherapeutic agents [2010175039] in 2017 by this industry relative to its total output.
	Rubber		Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	6.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of styrene-butadiene rubber (SBR), excluding latex [2025425000], Manufacturing of styrene-butadiene rubber (SBR), latex [2025450000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 37.2%, which represents the percent of styrene-butadiene rubber produced using solution (which uses lithium) rather than emulsion (which does not use lithium) in 2023 (Grand View Research, 2023g).
	Other: paints		Paint and coating manufacturing [325510]	7.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
	Other: electronics		Other electronic component manufacturing [33441A]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of crystals, filters, piezoelectric, and other related electronic devices (excluding microwave filters) [2033825000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 3.3%. This factor represents lithium niobate's share of the 2017 global market share of photonic integrated circuits (Gaurav, 2017).
	Other: inorganic chemicals		Other basic inorganic chemical manufacturing [325180]	0.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

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					all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Magnesium compounds	Animal feed	The proportions of magnesium compounds' use by application in the United States were estimated based on reported production of the downstream chemicals (U.S. Geological Survey, 2025b) and their net imports, as calculated in this analysis. Some production quantities were withheld to avoid disclosing company proprietary information but included in this analysis. Because magnesium hydroxide production is downstream of magnesium chloride production, its production was subtracted from magnesium chloride production to avoid double-counting. Similarly, net imports of magnesium carbonate	Other animal food manufacturing [311119]	69.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of chicken and turkey feed, supplements, concentrates, and premixes [2034450000], Manufacturing of complete dairy cattle feed, supplements, concentrates, and premixes [2034475000], Manufacturing of complete swine feed, supplements, concentrates, and premixes [2034500000], Manufacturing of complete beef cattle feed, supplements, concentrates, and premixes [2034525000] in 2021 by this industry relative to its total output.
	Dyes		Synthetic dye and pigment manufacturing [325130]	6.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Fertilizer		Fertilizer manufacturing [325310]	12.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Glass		Glass and glass product manufacturing [327200]	4.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of machine-made pressed and blown table, kitchen, art, and novelty glassware [2007500000], Manufacturing of handmade pressed and blown glassware [2007525000], Manufacturing of flat glass (float, sheet, and plate process) [2026050000] in 2021 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Mineral wool insulation	and magnesium oxide were not assigned to a downstream chemical given that the production of the downstream chemical was already included. For each magnesium compound consumption, the applications were assigned based on to individual industries based on the data from Roskill Information Services Ltd. (2018a).	Mineral wool manufacturing [327993]	22.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Pharmaceuticals		Pharmaceutical preparation manufacturing [325412]	13.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of pharmaceutical preparations, vitamin, nutrient, and hematinic preparations, for human use [2010300000], Manufacturing of antacids and antidiarrheals, including acid neutralizing and products with coating functions [2010250006], Manufacturing of pharmaceutical preparations, acting on the digestive or the genito-urinary systems, for human use [2010250000] in 2017 by this industry relative to its total output.
	Pulp mills	Caustic calcined magnesium's use in agriculture was split 80%-20% between animal feed and fertilizer and in construction, its use was split 90%-10% between ready-mix concrete and mineral wood manufacturing. Consumption of magnesium compounds under different	Pulp mills [322110]	83.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of special alpha and dissolving woodpulp (sulfite and sulfate for chemical conversion, papermaking, and other uses), sulfate woodpulp (including soda), sulfite woodpulp, and other woodpulp [2023125000] in 2021 by this industry relative to its total output.
	Ready-mix concrete		Ready-mix concrete manufacturing [327320]	95.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of portland cement and other portland hydraulic cements (including oil well, white cement, blended cements, etc.), and masonry cement and cement clinker [2026400000], Manufacturing of ready-mix concrete [2040575000] in 2021 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Steel furnace linings	applications for the same BEA industry were merged.	Iron and steel mills and ferroalloy manufacturing [331110]	92.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Various other chemical products		All other chemical product and preparation manufacturing [3259A0]	15.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Magnesium metal	Aluminum alloys	The proportions of magnesium metal's use by application in the United States were obtained from the U.S. Geological Survey (2024; 2025b), some of which were aggregated to avoid releasing company proprietary information but used in this analysis at the most disaggregated level available. The undifferentiated "other" application category was split equally among the various uses.	Secondary smelting and alloying of aluminum [331314]	94.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of aluminum and aluminum-base alloy powders, paste, and flakes [2026990000], Manufacturing of aluminum ingot, including billet [2026995000] in 2018 by this industry relative to its total output.
	Castings		Nonferrous metal foundries [331520]	65.1	Assessment was based on the value of aluminum- and magnesium-based castings from the following NAPCS codes: Manufacturing of aluminum and aluminum-base alloy die-castings [2028100000], Manufacturing of aluminum and aluminum-base alloy sand castings (excluding cast aluminum cooking utensils) [2028125000], Manufacturing of aluminum and aluminum-base alloy permanent and semipermanent mold castings (excluding cast aluminum cooking utensils) [2028150000], Manufacturing of aluminum and aluminum-base alloy investment castings (excluding cast aluminum cooking utensils) [2028175000], Manufacturing of other aluminum and aluminum-base alloy castings, excluding die-castings (excluding cast aluminum cooking utensils)

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					[2028200000], Manufacturing of other nonferrous foundries castings (excluding die-casting and aluminum) including nickel and nickel-base alloy, zinc and zinc-base alloy, magnesium and magnesium-base alloy, and all other nonferrous castings [2028300000], Manufacturing of nonferrous metals and alloys (excluding aluminum) die-castings [2028250000], with the output of the latter two NAPCS codes associated with magnesium alloys being disaggregated based on data from the 2002 Economic Census (U.S. Census Bureau, 2004a).
	Cathodic protection		All other miscellaneous electrical equipment and component manufacturing [335999]	3.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other electrical equipment for industrial use, including industrial-use surge suppressors (excluding for electronic circuitry) [2016025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 16.7%, which was the estimated share associated with cathodic protection equipment based on data from the 2002 Economic Census (U.S. Census Bureau, 2004a).
	Chemicals		Other basic inorganic chemical manufacturing [325180]	0.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nondurable goods merchant wholesalers [424A00] industry.
	Desulfurization		Iron and steel mills and ferroalloy manufacturing [331110]	9.8	Assessment was based on the quantity of steel that would have used magnesium metal for desulfurization, which was estimated by dividing the quantity of magnesium metal used for desulfurization by 0.5 kg of magnesium required per metric tons of hot steel (Project Blue, 2025d). The result was then

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					divided by the total quantity of steel produced in the United States in 2023 (U.S. Geological Survey, 2025a) multiplied by the percent of this industry's output that is associated with steel production.
	Nodular iron		Ferrous metal foundries [331510]	17.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of ductile iron pressure pipe and fittings, all sizes [2027800000], Manufacturing of other ductile iron castings for automotive uses [2027825000], Manufacturing of all other ductile iron castings for all other uses, including valve, construction and utility, machinery, electric and electronic equipment, heat-resistant parts (including coke oven doors) [2027850000] in 2021 by this industry relative to its total output.
	Reducing agent		Nonferrous metal (except aluminum) smelting and refining [331410]	1.7	Assessment was based on the quantity of titanium sponge, beryllium metal, hafnium, and zirconium metal produced in the United States multiplied by their respective prices as a percent of the total industry output in 2023.
	Other: surgical equipment		Surgical and medical instrument manufacturing [339112]	1.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nondurable goods merchant wholesalers [424A00] industry.
	Other: sports equipment		Sporting and athletic goods manufacturing [339920]	2.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nondurable goods merchant wholesalers [424A00] industry.
	Other: matches		All other chemical product and preparation manufacturing [3259A0]	0.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of smoking accessories, including matches, cigarette

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					lighters, cigarette holders, tobacco pipes, etc. [2004425000] in 2021 by this industry relative to its total output.
	Other: bicycles		Motorcycle, bicycle, and parts manufacturing [336991]	0.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of bicycles and other cycles, all types, except children's sidewalk bikes [2008700000], Manufacturing of parts for bicycles, unicycles, and adult tricycles [2032750000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 3.8%, which was the reported market share of bicycles with magnesium alloy frames in 2021 (Aikerly, 2022).
	Other: fireworks		All other chemical product and preparation manufacturing [3259A0]	0.04	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of fireworks and pyrotechnics, including flares, igniters (jet fuel or other), railroad torpedoes, toy pistol caps, etc. [2046700000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 14.3% (one-seventh) given that one of the seven main colors of fireworks used magnesium (U.S. Geological Survey, 2020b).
Manganese alloys	Steels	All domestic manganese alloy consumption was assumed to be for steel production.	Iron and steel mills and ferroalloy manufacturing [331110]	88.3	Given that all steels require some manganese, the percent of this industry's output that were steel products was split between manganese alloys and manganese metal proportionally based on the share of each commodity's apparent consumption in this application.
Manganese dioxide	Batteries, primary	Given that the United States did not manufacture lithium-manganese oxide rechargeable batteries in	Primary battery manufacturing [335912]	58.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of primary batteries, excluding lead acid [2010950000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 63%, which

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		2023, all manganese dioxide consumption was assumed to be for primary batteries.			represented the approximate percent of global primary battery that used manganese (alkaline and zinc-carbon) (Market.U.S., 2025b) in 2024.
Manganese metal	Steels	The proportions of manganese metal use by application were obtained from the U.S. Geological Survey (2025b), which were withheld to avoid releasing company proprietary information but used in this analysis.	Iron and steel mills and ferroalloy manufacturing [331110]	6.4	Given that all steels require some manganese, the percent of this industry's output that were steel products was split between manganese alloys and manganese metal proportionally based on the share of each commodity's apparent consumption in this application.
	Aluminum alloys		Secondary smelting and alloying of aluminum [331314]	16	Assessment was based on the percent of wrought alloys and extrusion billets that were Series 3000 (Global Growth Insights, 2024).
Manganese ore	Ferro- and silicomanganese	The proportions of manganese ore use in the United States was determined based on the reported production of ferro- and silicomanganese and manganese dioxide (Project Blue, 2024; Project Blue, 2025e).	Iron and steel mills and ferroalloy manufacturing [331110]	0.2	Assessment was based on the quantity of ferro- and silicomanganese produced in the United States multiplied each of their reported price as a percent of this industry's output in 2023.
	Manganese dioxide		Other basic inorganic chemical manufacturing [325180]	0.4	Assessment was based on the quantity of manganese dioxide production in the United States multiplied by the reported price of manganese dioxide as percent of the industry's output in 2023
Manganese sulfate (high purity)	Batteries, rechargeable	All high purity manganese sulfate consumption was assumed to be entirely for lithium-ion batteries.	Storage battery manufacturing [335911]	45.1	Assessment was based on the value of lithium-ion battery cells manufactured in the United States, which was based production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a) relative to the total output of this industry in 2023.
Mica	Joint compounds	The proportions of mica's use by application in the United States were obtained from the U.S.	Lime and gypsum product manufacturing [327400]	15.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of gypsum building plasters [207325000], Manufacturing of other gypsum products

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		Geological Survey for ground mica sold or used (U.S. Geological Survey, 2025b).			[2037400000] in 2021 by this industry relative to its total output.
	Paints and coatings	The use of mica in well drilling, welding rods, brick and ceramic tiles, roofing, and undifferentiated "other" applications were aggregated by the reference to protect company proprietary information but were disaggregated in the analysis. The undifferentiated "other" category within the withheld data was assumed to be entirely for cosmetics.	Paint and coating manufacturing [325510]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of paints and enamels, automotive, other transportation and machinery refinishing, including primers [2040350012] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 14%. This factor represents the approximate share of automotive pearlescent paint relative to all automotive paints based on the North American market share for all white pearl and half of the black effect paint in 2022 (Axalta Coating Systems, 2022) multiplied by an 80% share for mica in pearlescent pigments and paints (Schipper and Cowan, 2018)
	Plastics		Other plastics product manufacturing [326190]	18.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of fabricated plastics components, housings, accessories, and parts for motor vehicles (excluding foam and reinforced plastics) [2029175003], Manufacturing of transportation reinforced and fiberglass plastics products [2029200000] in 2017 by this industry relative to its total output.
	Well drilling		Drilling oil and gas wells [213111]	5.1	Assessment was based on the value of shipments of the following NAPCS code: Drilling oil and gas wells, including drilling in, spudding in, or tailing in [1001625000] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 6.7%. Flake type lost circulation material comprise 20% of global market (Verified Market Reports, 2025i). Mica, cellophane, and calcium carbonate are all noted as common flake lost circulation material. Mica was thus assumed to

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					comprise one-third of the flake lost circulation material market.
	Welding rods		Other general purpose machinery manufacturing [33399A]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the All other chemical product and preparation manufacturing [3259A0] industry.
	Brick and ceramic tile		Clay product and refractory manufacturing [327100]	0.03	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Ground or treated mineral and earth manufacturing [327992] industry.
	Roofing		Asphalt shingle and coating materials manufacturing [324122]	0.02	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Ground or treated mineral and earth manufacturing [327992] industry.
	Cosmetics		Toilet preparation manufacturing [325620]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the All other chemical product and preparation manufacturing [3259A0] industry.
Molybdenum	Steels	The proportions of molybdenum's used by application in the United States were obtained from the U.S. Geological Survey (2025b), some of which were withheld to avoid releasing company	Iron and steel mills and ferroalloy manufacturing [331110]	3.7	Assessment was based on the value of molybdenum-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of molybdenum-containing steel produced, the quantity of molybdenum consumed in various types of steel was divided by estimated elemental contents of molybdenum-containing steels (Roskill Information Services Ltd., 2019b) and then multiplied by a unit

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		proprietary information but used in this analysis.			value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).
	Superalloys: aerospace	Molybdenum's use in superalloys was split into two applications, aerospace and industrial turbines, 80% and 20%, respectively.	Aircraft engine and engine parts manufacturing [336412]	86.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output.
	Superalloys: industrial turbines	Molybdenum's use in undifferentiated mill products (meaning those excluding electric lamp bulbs), were disaggregated into different industries based on data reported by the International Molybdenum Association (Walser and Shields, 2007), with the	Turbine and turbine generator set units manufacturing [333611]	57.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output.
	Cast iron	undifferentiated "other" category being allocated to BEA industries identified by the U.S. Census Bureau (2024) as having imported a	Ferrous metal foundries [331510]	1.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Catalyst	molybdenum-containing product (based on the HTS code noted in appendix 2) in 2022 and allocated the based on	Petroleum refineries [324110]	37.5	Assessment was based on the charge capacity of catalytic hydrotreating in the United States in 2023 as a percent of atmospheric crude oil distillation capacity (U.S. Energy Information Administration, 2024b) multiplied by 42%, which represents that

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		each industry's monetary output in 2023.			approximate share of molybdenum-based catalysts used in hydrodesulfurization (Strategy & Stats Insider, 2022).
	Lubricants	The U.S. Geological Survey's undifferentiated "other" uses of molybdenum were assumed to be for assumed to be minor quantities of molybdenum for fertilizer and micronutrient and split based on the quantity reported for ammonia molybdenum and sodium molybdate, respectively.	Other petroleum and coal products manufacturing [324190]	14.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Pigments		Synthetic dye and pigment manufacturing [325130]	0.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Mill products: coatings and heat treating		Coating, engraving, heat treating and allied activities [332800]	18.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: semiconductors		Semiconductor and related device manufacturing [334413]	10.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: glassmaking equipment		Other industrial machinery manufacturing [33329A]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of glassmaking machinery and equipment, including machines for hot working glass or glassware, excluding parts [2014325000] in 2021 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Mill products: medical X-ray tubes and detectors		Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.04	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of parts and accessories for X-ray equipment [2045213000] in 2021 by this industry relative to its total output.
	Mill products: automotive parts		Other motor vehicle parts manufacturing [336390]	53.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: industrial machinery		All other miscellaneous manufacturing [339990]	4.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: household appliances		Major household appliance manufacturing [335220]	9.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: other general-purpose machinery		Other general purpose machinery manufacturing [33399A]	44.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: other commercial and service industry machinery		Other commercial and service industry machinery manufacturing [333318]	55.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					(except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: valves and fittings		Valve and fittings other than plumbing [33291A]	38.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: spring and wire product		Spring and wire product manufacturing [332600]	13.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: hardware		Turned product and screw, nut, and bolt manufacturing [332720]	6.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: forgings		All other forging, stamping, and sintering [33211A]	0.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: custom roll forming		Custom roll forming [332114]	13.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Mill products: stampings		Metal crown, closure, and other metal stamping (except automotive) [332119]	5.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill products: electrical equipment		All other miscellaneous electrical equipment and component manufacturing [335999]	1.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Welding materials		Coating, engraving, heat treating and allied activities [332800]	0.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Electric lamp		Electric lamp bulb and part manufacturing [335110]	16.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electric lamp bulbs and tubes (including sealed beam lamp bulbs) [2051400000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 20%. This factor represents the approximate percent of U.S. lamp shipments that were halogen-based in 2022 (National Electrical Manufacturers Association, 2023).
	Cemented carbides		Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	0.03	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Wear and corrosion		Coating, engraving, heat treating and allied activities [332800]	0.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Magnetic alloys		Other fabricated metal manufacturing [332999]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Nickel alloys (excluding superalloys)		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	0.02	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Other alloys		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	0.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Other chemicals		Other basic inorganic chemical manufacturing [325180]	0.002	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: fertilizer		Fertilizer manufacturing [325310]	0.03	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: micronutrient		Vegetable and melon farming [111200]	0.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Nickel, mined	Processed nickel	Most mined nickel was exported for processing outside of the United States. Nickel produced as a byproduct platinum-group metal mining was processed into crystalline nickel sulfate.(U.S. Geological Survey, 2025a)	Nonferrous metal (except aluminum) smelting and refining [331410]	1.0	Assessment was based on the quantity of nickel ores and concentrates consumed in the United States multiplied by the reported price as a percent of this industry's output in 2023.
Nickel, primary refined	Batteries, rechargeable	<p>The proportions of primary refined nickel consumed in the United States by application were obtained from the U.S. Geological Survey (2025b).</p> <p>Primary refined nickel's use in superalloys was split 80%-20% between aerospace and industrial turbines, respectively.</p> <p>Additionally, the net imports of nickel sulfate</p>	Storage battery manufacturing [335911]	49.8	Assessment was based on the value of the production of lithium-ion, nickel-metal hydride, nickel-cadmium, and nickel-zinc rechargeable batteries. The value of lithium-ion battery cells manufactured in the United States that contain nickel was based production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a), relative to the total output of this industry in 2023. The value of the other nickel-containing recharge batteries was estimated by subtracting the value of U.S. manufacturing of lithium-ion battery cells and lead acid batteries from the total industry output of the storage battery manufacturing industry [335911] in 2023. The result was then multiplied by 83%, which represents nickel-metal hydride, nickel-cadmium, and nickel-zinc battery sales' global share among

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		and nickel contained in lithium-ion battery cathodes were assumed to be consumed for the production of lithium-ion batteries.			share of all other storage battery (excluding lead-acid and lithium-ion batteries) based on data from Mordor Intelligence (2022a).
	Magnetic alloys		Other fabricated metal manufacturing [332999]	1.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of permanent magnets, excluding ceramic permanent magnets [2034200000] in 2021 by this industry relative to its total output.
	Other alloys		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	10.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nickel and nickel-base alloy mill shapes, excluding nickel and nickel alloy wire [2027375000], Manufacturing of nickel and nickel alloy wire [2033210000] in 2020 by this industry relative to its total output.
	Other chemical uses		Other basic inorganic chemical manufacturing [325180]	2.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Plating		Coating, engraving, heat treating and allied activities [332800]	7.4	Assessment was based on the value of shipments of the following NAPCS code: Electroplating, plating, polishing, anodizing, and coloring [2053500000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 30%, which represented the percent of global electroplating market that was based on nickel (Global Growth Insights, 2025a).
	Stainless and other steel alloys		Iron and steel mills and ferroalloy manufacturing [331110]	1.5	Assessment was based on the value of nickel-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of nickel-containing steel produced, the quantity of nickel consumed in various types of steel was divided by estimated elemental contents of

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					<p>nickel-containing steels (Roskill Information Services Ltd., 2018b) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).</p> <p>The percent of this industry's output might seem lower than expected because a large proportion of stainless and other nickel-containing steels were produced from secondary (recycled) sources, which were excluded from the analysis.</p>
	Superalloys: aerospace		Aircraft engine and engine parts manufacturing [336412]	84.2	<p>Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 97%, the percent of superalloys that were estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).</p>
	Superalloys: industrial turbines		Turbine and turbine generator set units manufacturing [333611]	52.6	<p>Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a</p>

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					factor of 91%, the percent of superalloys that was estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
Niobium	Steels	<p>The use of niobium by application was determined based on trade data.</p> <p>Specifically, niobium's use in steel was based on net imports of two HTS codes for ferroniobium (7202930000 and 7202938000).</p>	Iron and steel mills and ferroalloy manufacturing [331110]	13.3	Assessment was based on the value of niobium-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of niobium-containing steel produced, the quantity of niobium consumed in various types of steel was divided by estimated elemental contents of niobium-containing steels (McCaffrey and others, 2023) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).
	Superalloys: aerospace	Niobium's use in superalloys was based on the net imports of HTS 7202934000 along with the net imports of HTS 8112924000 that had a trade transaction unit value between \$30 and \$55 per kg, which was done to determine the subset of trades that involved nickel-niobium alloys. Superalloys were then subdivided into sub-applications based on data from Eckard (2017).	Aircraft engine and engine parts manufacturing [336412]	71.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], and Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 82.6%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: industrial turbines		Turbine and turbine generator set units manufacturing [333611]	39.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines

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		Niobium's use in high performance alloys and superconductors was based on the net imports of HTS 8112924000 with unit values greater than \$55/kg, which were then split equally between the two applications.			and other vapor turbines [2015725000], and Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 69.1%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: nuclear reactor	Additionally, net imports of niobium pentoxide were allocated into specific applications based on data from Mordor Intelligence (2022b). Specifically, niobium pentoxide used to produce niobium metal was equally allocated to superconductors and high-performance alloys. Niobium pentoxide used to produce ceramics, optical glass, superalloys, supercapacitors, and other applications was allocated to ceramic capacitors, crystals and	Power boiler and heat exchanger manufacturing [332410]	15.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nuclear reactor steam supply systems, heat exchangers and condensers, pressurizers, components, and auxiliary equipment [2016425000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 69.1%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: industrial processes		Metal tank (heavy gauge) manufacturing [332420]	1.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nonferrous metal process pressure vessels, tanks, and kettles for refineries, chemical plants, paper mills (more than 24 in. outside diameter and not less than 5 cu ft cap.), custom fabricated at the factory [2016350003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 45.8%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).

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	Superalloys: oil and gas	filters, superalloys, supercapacitors, and catalysts, respectively.	Mining and oil and gas field machinery manufacturing [333130]	36.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of rotary oil and gas field drilling machinery and equipment, excluding parts [2013050000], Manufacturing of other oil and gas field drilling machinery and equipment, excluding parts [2013075000], Manufacturing of oil and gas field production machinery and equipment (excluding pumps and parts) [2013100000], and Manufacturing of oil and gas field derricks, substructures and accessories, including well-surveying machinery and equipment and well-logging equipment [2013150000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 82.1%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: automotive		Other motor vehicle parts manufacturing [336390]	3.3	Assessment was based on the value of the North American turbocharger market (Global Market Insights, 2025a) multiplied by 51% to approximate the share of superalloys that were nickel-based (Eckard, 2017) divided by the total industry output in 2023.
	Superconductors		Electromedical and electrotherapeutic apparatus manufacturing [334510]	5.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of magnetic resonance imaging equipment (MRI) [2018000003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 79%, which represents the percent of MRI machines that were mid- or high-field strength (Grand View Research, 2025b) and used low

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					temperature superconductors and thus typically use niobium (BCC Research, 2020).
	High performance alloys		Aircraft manufacturing [336411]	43.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of military aircraft, including all aircraft for U.S. military and any other aircraft built to military specifications [2012100000] in 2021 by this industry relative to its total output. It was thus assumed that niobium was more likely used in military as opposed to civilian aircraft.
	Ceramic capacitors		Other electronic component manufacturing [33441A]	1.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of capacitors for electronic circuitry [2033725000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 53%. This factor represents the proportion of Class II ceramic capacitors, which likely used niobium, multiplied by the proportion of capacitors that were ceramic (Gagliardi, 2019).
	Supercapacitors		Other electronic component manufacturing [33441A]	0.02	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of capacitors for electronic circuitry [2033725000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 0.55%. This factor represents the proportion of metal oxide type supercapacitor within hybrid and pseudo-capacitors, which likely used niobium, multiplied by the 2023 proportional value of the supercapacitors market (BCC Research, 2023) to the 2023 capacitors market (Gagliardi, 2019).
	Crystals and filters		Other electronic component manufacturing [33441A]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of crystals, filters, piezoelectric, and other related

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					electronic devices (excluding microwave filters) [2033825000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 3.3%. This factor represents lithium niobate's share of the 2017 global market share of photonic integrated circuits (Gaurav, 2017).
	Catalysts		Other basic inorganic chemical manufacturing [325180]	0.05	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Palladium	Automotive: catalytic converters for light duty truck and utility vehicles	The proportions of palladium's use by application were obtained from Cowley (2024). These data pertain to the application fractions of North American (specifically Canada and the United States) but were assumed applicable to the United States. The "investment" application was excluded from this analysis.	Light truck and utility vehicle manufacturing [336112]	97.3	Assessment was based on the percent of light duty trucks and utility vehicles manufactured in the United States that use catalytic converters (meaning all those that were not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Automotive: catalytic converters for automobiles		Automobile manufacturing [336111]	78.3	Assessment was based on the percent of automobiles manufactured in the United States that use catalytic converters (meaning all those that were not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Automotive: catalytic converters for heavy duty vehicles		Heavy duty truck manufacturing [336120]	98.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of buses, complete, including military (excluding trolley buses) [2011900000], Manufacturing of heavy-duty trucks, including heavy-duty truck, tractor, and bus chassis [2011910000], and Manufacturing of firefighting vehicles and other heavy trucks, complete [2011925000] in 2021 by this industry relative to its total output.
	Chemical: hydrogen peroxide synthesis	The proportion of palladium's use in the automotive application was split 97%-3% among the light truck and utility vehicle	Other basic inorganic chemical manufacturing [325180]	1.5	Assessment was based on the value of U.S. hydrogen peroxide consumption in 2023, as reported by Grand View Research (2020), less U.S. net

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		manufacturing and heavy duty truck manufacturing, respectively, based on data from Johnson Matthey plc (2016). Light duty vehicle manufacturing was split between light duty truck and utility vehicle manufacturing and automobile manufacturing based on 2023 industry output.			imports of hydrogen peroxide (HTS: 284700) relative to this industry's output.
	Chemical: acetaldehyde synthesis (Wacker-Hoechst process)		Other basic organic chemical manufacturing [325190]	0.1	Assessment was based on the value of U.S. acetaldehyde consumption in 2023, as reported by Grand View Research (2021), less U.S. net imports of acetaldehyde (HS: 291212) relative to this industry's output.
	Chemical: purified terephthalic acid (PTA) synthesis		Other basic organic chemical manufacturing [325190]	3.2	Assessment was based on reported U.S. purified terephthalic acid production capacity of 4,120 thousand metric tons (Hay, 2018) and a unit price of purified terephthalic acid of \$1,100 per metric ton (ChemAnalyst, 2024d).
	Chemical: for vinyl acetate monomer synthesis		Other basic organic chemical manufacturing [325190]	2.8	Assessment was based on reported U.S. vinyl acetate monomer production capacity of 1,835 thousand metric tons and unit value of vinyl acetate monomer of \$2,000 per ton (Matherne, 2021).
	Chemical: catchment gauzes in nitric acid production		Fertilizer manufacturing [325310]	1.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nitric acid [2034625003] in 2017 relative to the industry's total output.
	Chemical: pharmaceutical preparation		Pharmaceutical preparation manufacturing [325412]	70.0	Assessment was based on the percent of pharmaceuticals that are manufactured with palladium catalysts (Shipman, 2018).
	Dental equipment and supplies	The proportion of palladium's use in the dental application was split proportionally based of the value of shipments of the Manufacturing of dental metals, artificial teeth not customized for	Dental equipment and supplies manufacturing [339114]	5.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 59%. This factor represents the market share of dental metals that were based on palladium and gold (where palladium was often an alloy) in 2022 (KBV Research, 2024b).

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	Dental laboratories	individual application, and other dental laboratory supplies [2045975000] NAPCS code reported by those two associated BEA industries. The proportion of palladium's use the electrical & electronics application was first split among the BEA industries based on additional information from Cowley (2024) regarding platinum-group metal use in electronic pastes, plating, and other electronics uses and then split further based the expenditure of the associated BEA industries on gold and other precious metals (Material code: 33141911) reported in 2012 Economic Census (U.S. Census Bureau, 2012a).	Dental laboratories [339116]	0.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 59%. This factor represents the market share of dental metals that were based on palladium and gold (where palladium was often an alloy) in 2022 (KBV Research, 2024b).
	Electrical & electronics: multi-layer ceramic capacitors		Other electronic component manufacturing [33441A]	0.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of capacitors for electronic circuitry [2033725000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 18.3%. This factor represents the market share of electronic capacitors that were multilayer ceramic capacitors that were palladium-based (Zogby, 2018).
	Electrical & electronics: other electronic components		Other electronic component manufacturing [33441A]	9.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Electrical & electronics: semiconductors		Semiconductor and related device manufacturing [334413]	35.0	Assessment was based on the percent of the global bonding wire market that used palladium in 2017 (Lau and Lam, 2020).
	Electrical & electronics: printed circuit assemblies		Printed circuit assembly (electronic assembly) manufacturing [334418]	5.0	Assessment was based on the percent of global printed circuit board finishes that used gold in 2016 (Shah, 2018).
	Jewelry	The proportion of palladium's use in the	Jewelry and silverware manufacturing [339910]	0.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

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		other application was assumed to be palladium's use in petroleum refining.			all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry in 2023.
	Pollution control		Other engine equipment manufacturing [333618]	20.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of parts and accessories for internal combustion engines, excluding aircraft and gas automotive engines and turbines [2042440000] in 2017 relative to the industry's total output.
	Other: petroleum refining		Petroleum refineries [324110]	16.7	Assessment was based on the U.S. refinery catalytic hydrocracking downstream charge capacity relative to total downstream charge capacity in 2023 (U.S. Energy Information Administration, 2024b).
Phosphates	Fertilizer	In the United States, 97% of phosphates were assumed to be for fertilizer, with the remaining 3% for other uses (U.S. Geological Survey, 2025a)	Fertilizer manufacturing [325310]	41.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of superphosphates and other phosphatic fertilizer materials [2034700000], Manufacturing of mixed fertilizers, dry [2034725000], Manufacturing of mixed fertilizers, liquid [2034750000] in 2021 by this industry relative to its total output.
	Other uses		Other basic inorganic chemical manufacturing [325180]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of phosphoric acid [2024525000] in 2021 by this industry relative to its total output.
Platinum	Automotive: catalytic converters for light duty truck and utility vehicles	The proportions of platinum's use by application were obtained from Cowley (2024). These data pertain to the application fractions of North American (specifically	Light truck and utility vehicle manufacturing [336112]	97.3	Assessment was based on the percent of light duty trucks and utility vehicles manufactured in the United States that use catalytic converters (meaning all those that were not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Automotive: catalytic converters for automobiles		Automobile manufacturing [336111]	78.3	Assessment was based on the percent of automobiles manufactured in the United States that use catalytic converters (meaning all those that were

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		Canada and the United States) but were assumed applicable to the United States. The "investment" application was excluded from this analysis.			not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Automotive: catalytic converters for heavy duty vehicles	The proportion of platinum's use in the automotive application was split roughly 84%-16% among the light vehicle manufacturing and heavy duty truck manufacturing, respectively, based on data from Johnson Matthey plc (2016). Light duty vehicle manufacturing was split between light duty truck and utility vehicle manufacturing and automobile manufacturing based on 2023 industry output.	Heavy duty truck manufacturing [336120]	98.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of buses, complete, including military (excluding trolley buses) [2011900000], Manufacturing of heavy-duty trucks, including heavy-duty truck, tractor, and bus chassis [2011910000], Manufacturing of firefighting vehicles and other heavy trucks, complete [2011925000] in 2021 by this industry relative to its total output.
	Chemical: silicones synthesis		Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	8.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of silicone elastomers [2025550000] in 2017 by this industry relative to its total output.
	Chemical: para-xylene synthesis		Petrochemical manufacturing [325110]	4.5	Assessment was based on an estimated production capacity of U.S. para-xylene production (~3,160 thousand metric tons) (ICIS, 2020) and an average unit value of para-xylene of \$1,062 per metric ton (ChemAnalyst, 2024c) relative to the industry's output in 2023.
	Chemical: nitric acid synthesis		Fertilizer manufacturing [325310]	1.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nitric acid [2034625003] in 2017 relative to the industry's total output.
	Dental & biomedical: pacemakers, defibrillators, cochlear implants		Electromedical and electrotherapeutic apparatus manufacturing [334510]	6.9	Assessment was based on based on the sum of the U.S. market of pacemakers (Grand View Research, 2022d) and cochlear implants (Grand View Research, 2023a) and value of shipments from Manufacturing of defibrillators [2018000024], the latter which was multiplied by 59% to approximate the share of defibrillators that were implantable (The Brainy Insights, 2023), relative to the output of the industry in 2021.

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	Dental & biomedical: stents and catheters	industries based on information noted in Nassar (2015). The proportion of platinum's use in the dental & biomedical application was split among the associated	Surgical and medical instrument manufacturing [339112]	7.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of stents [2045875031] and Manufacturing of surgical and medical catheters [2045775000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 45%. This factor represents the percent of coronary stent that use platinum-alloys in the United States (U.S. Department of Energy, 2012).
	Dental & biomedical: dental materials	BEA industries based on information noted by Butler (2010). The proportion of platinum's use in the dental application was further split proportionally based of the value of shipments of the Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] NAPCS code reported by those two associated BEA industries.	Dental equipment and supplies manufacturing [339114]	4.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 51.5%. This factor represents the market share of dental metals that were based on gold (where platinum was often an alloy) in 2022 (KBV Research, 2024b).
	Dental & biomedical: dental laboratories	teeth not customized for individual application, and other dental laboratory supplies [2045975000] NAPCS code reported by those two associated BEA industries.	Dental laboratories [339116]	0.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 51.5%. This factor represents the approximate market share of dental metals that were based on high-gold dental alloys, where platinum was often an alloying element, in 2022 (KBV Research, 2024b).
	Dental & biomedical: anti-cancer drugs	The proportion of platinum's use in the electrical & electronics application was split among the associated	Pharmaceutical preparation manufacturing [325412]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of anti-neoplastic agents, including radioactive isotopes, and specific anti-neoplastic agents [2010150027] in

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		BEA industries based on information noted in Cowley (2024).			2017 relative to the industry's total output. The result was then multiplied by a factor of 15%. This factor represents the approximate percent of anti-cancer drugs that are based on platinum (BioSpace, 2021).
	Electrical & electronics: hard disk drives	The proportion of platinum's use in other applications was split based on information from Kendall (2006). The proportion of platinum's use was further split between Aircraft engine and engine parts manufacturing [336412] and Turbine and turbine generator set units manufacturing [333611] proportionally based on the value of shipments on the noted NAPCS codes.	Computer storage device manufacturing [334112]	17.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of disk subsystems and disk arrays for multiuser computer systems [2011625003] and Manufacturing of disk drives (all sizes) [2011625006] in 2017 by this industry relative to its total output.
	Electrical & electronics: thermocouples		Industrial process variable instruments manufacturing [334513]	0.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other temperature measuring instruments [2017625033], Manufacturing of primary temperature sensors, excluding aircraft types, thermocouples [2017625036], and Manufacturing of electrical and electronic temperature measuring instruments [2017625031] in 2017 relative to the industry's total output. The result was then multiplied by a factor of 7.9%. This factor represents the global market share of precious metal thermocouples (Dhapte, 2025; Market Reports World, 2022).
	Electrical & electronics: other electronic components		Other electronic component manufacturing [33441A]	7.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Glass manufacturing equipment		Glass and glass product manufacturing [327200]	17.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other glass fiber, textile-type (including yarn, strand, staple yarn, sliver, roving, chopped strand, and milled glass fiber) [2020575000], Manufacturing of glass fiber

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					mat, textile-type [2021225000], and Manufacturing of flat glass (float, sheet, and plate process) [2026050000] in 2021 by this industry relative to its total output.
	Jewelry		Jewelry and silverware manufacturing [339910]	10.4	Assessment was based on the value of the calculated apparent consumption of this commodity by this industry in 2023 multiplied by the ratio of revenue generated by this industry to the total material expenditure of this industry in 2017 based on from data reported in the Economic Census, relative to the total output of this industry in 2023.
	Petroleum		Petroleum refineries [324110]	25.0	Assessment was based on the U.S. refinery catalytic reforming downstream charge capacity relative to total downstream charge capacity in 2023 (U.S. Energy Information Administration, 2024b).
	Pollution control		Other engine equipment manufacturing [333618]	20.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of parts and accessories for internal combustion engines, excluding aircraft and gas automotive engines and turbines [2042440000] in 2017 by this industry relative to its total output.
	Other: aircraft turbine blade casting and coating		Aircraft engine and engine parts manufacturing [336412]	86.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], and Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Other: gas turbine blade casting and coating		Turbine and turbine generator set units manufacturing [333611]	57.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], and Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output.
	Other: spark plugs		Motor vehicle electrical and electronic equipment manufacturing [336320]	0.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of spark plugs (all types) [2029575000] in 2021 relative to the industry's total output. The result was then multiplied by a factor of 12.5% as it represents the approximate percent of spark plugs that used platinum.
Potash	Fertilizer	It was estimated that 95% of potash's was for fertilizer, with the remaining 5% being used for all other chemicals (Natural Resources Canada, 2025; U.S. Bureau of Mines, 1985).	Fertilizer manufacturing [325310]	27.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of mixed fertilizers, dry [2034725000], Manufacturing of mixed fertilizers, liquid [2034750000] in 2021 by this industry relative to its total output.
	Chemicals		Other basic inorganic chemical manufacturing [325180]	5.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of potassium hydroxide (caustic potash) liquid (including liquid later converted to dry or solid) (Basis - 88-92%, KOH) [2024675003], Manufacturing of potassium and sodium compounds, excluding bleaches, alkalis, and alum [2024575000] in 2017 by this industry relative to its total output.
Rare earth elements	Batteries, nickel-metal hydride	U.S. consumption by individual rare earth element was disaggregated into	Storage battery manufacturing [335911]	3.8	Rare earth elements were used in nickel-metal hydride rechargeable batteries. To estimate the value of these products, the value of U.S. manufacturing of lithium-ion battery cells and lead acid batteries were subtracted from the total industry

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		consumption by application based on global consumption for each of the applications by each rare earth element based on data from Project Blue (2025f). Because the Project Blue rare earth consumption data for magnets include only raw material inputs used to make magnets and do not include imports magnet materials, imports for magnet materials for the two different magnet types (neodymium-iron-boron and samarium-cobalt) were added to their respective rare earth element consumption estimates based on the previously described import data.			output of the storage battery manufacturing industry [335911] in 2023. The value of lithium-ion battery cells manufactured in the United States was based on production and cell cost data from Benchmark Mineral Intelligence Ltd. (2023c; 2023a) relative to the total output of this industry. The value of lead-acid battery manufacturing was based on sum of the sale revenues from the following NAPCS codes, averaged for years 2021 and 2020: Manufacturing of storage batteries, lead-acid-type, BCI dimensional size group 8D (1.5 cu ft (.042 cu m) and smaller) [2030050000], Manufacturing of motive-power-type lead acid storage batteries, larger than BCI dimensional size group 8D (1.5 cu ft (.042 cu m)), including mining and industrial locomotive [2030075000], Manufacturing of all other lead acid storage batteries, larger than BCI dimensional size group 8D (1.6 cu ft (.042 cu m)), including communication and standby emergency [2030100000]. The result was then multiplied by 66%, which represents nickel-metal hydride battery sales' global share among share of all other storage battery (excluding lead-acid and lithium-ion batteries) based on data from Mordor Intelligence (2022a).
	Catalysts: catalytic converters for light duty trucks and utility vehicles		Light truck and utility vehicle manufacturing [336112]	97.3	Assessment was based on the percent of light duty trucks and utility vehicles manufactured in the United States that use catalytic converters (meaning all those that were not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Catalysts: catalytic converters for automobiles		Automobile manufacturing [336111]	78.3	Assessment was based on the percent of automobiles manufactured in the United States that use catalytic converters (meaning all those that were

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		Rare earth element consumption in automotive catalytic converters was split 90%-10% between light-duty vehicles and heavy-duty vehicles. Light duty vehicle manufacturing was split between light duty truck and utility vehicle manufacturing and automobile manufacturing based on 2023 industry output. In addition to the consumption of rare earth elements to manufacture permanent magnets, the United States also imported rare earth magnets. Rare earth element consumption in neodymium-iron-boron magnets was split based proportional the global consumption of neodymium-iron-boron magnets by application category noted by Project Blue (2025f),			not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Catalysts: catalytic converters for heavy duty vehicles		Heavy duty truck manufacturing [336120]	98.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of buses, complete, including military (excluding trolley buses) [2011900000], Manufacturing of heavy-duty trucks, including heavy-duty truck, tractor, and bus chassis [2011910000], and Manufacturing of firefighting vehicles and other heavy trucks, complete [2011925000] in 2021 by this industry relative to its total output.
	Catalyst: fluid catalytic cracking		Petroleum refineries [324110]	38.1	Assessment was based on the U.S. refinery catalytic cracking downstream charge capacity relative to total downstream charge capacity in 2023 (U.S. Energy Information Administration, 2024b).
	Ceramics: thermal barrier coatings for aircraft turbines		Aircraft engine and engine parts manufacturing [336412]	71.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 82.6%. Percent of superalloys that were estimated to be nickel-based for this application in 2016 (BCC Research)
	Ceramics: thermal barrier coatings for industrial gas turbines		Turbine and turbine generator set units manufacturing [333611]	39.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		excluding wind turbines because it was believed that U.S. manufactured wind turbines used gearboxes in 2023.			and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 69.1%. Percent of superalloys that were estimated to be nickel-based for this application in 2016 (BCC Research)
	Display panels	Neodymium-iron-boron magnets used in consumer electronics were split between hard disk drives and other electronics based on data from Roskill Information Services Ltd. (2021a).	Other electronic component manufacturing [33441A]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of all other specialized electronic hardware [2033925018] in 2017 by this industry relative to its total output. This result was then multiplied by a factor of 4.8%. This factor represents the value of shipments of liquid crystal displays and other liquid devices (334419E150) as a percent of the value of shipments of Manufacturing of all other specialized electronic hardware [2033925018] in 2004 (U.S. Census Bureau, 2005).
	Fiber optics	Neodymium-iron-boron magnets used in electric vehicle motors was split between light duty truck and utility vehicle manufacturing and automobile manufacturing based on their market share in their respective industries.	Communication and energy wire and cable manufacturing [335920]	2.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of fiber optic cable, for communications applications [2039150000], Manufacturing of fiber optic cable, for all other applications [2039175000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 10.5. This factor represents the value of the global erbium doped fiber amplifier market (Verified Market Reports, 2025f) as a percent of the global fiber optic market in 2024 (Precedence Research, 2025).
	Magnetic alloys	Neodymium-iron-boron magnets used "other"	Other fabricated metal manufacturing [332999]	1.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of permanent magnets, excluding ceramic permanent

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		applications were split equally between			magnets [2034200000] in 2021 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: power steering	medical, guided missiles, and search, detection, and navigation instruments. Rare earth element consumption in samarium-cobalt magnets was between	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing [3363A0]	11.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other motor vehicle steering and suspension components, including motor vehicle ball joints [2042675000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 55%. This factor represents the approximate share of motor vehicle steering that use rare earth permanent magnets (Stanford Magnets, 2024).
	Magnets, neodymium-iron-boron: automotive electronics	different four sub-applications based on their allocated revenues shares.	Audio and video equipment manufacturing [334300]	4.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of speakers for automobiles [2032400000] in 2021 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: consumer electronics, hard disk drives	Rare earth element consumption in ceramics was split 80%-20% between thermal barrier coatings for aerospace turbine blades and industrial gas turbine blades, respectively.	Computer storage device manufacturing [334112]	17.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of disk subsystems and disk arrays for multiuser computer systems [2011625003] and Manufacturing of disk drives (all sizes) [2011625006] in 2017 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: consumer electronics, other	For the "other" application category, all sub-applications were split equally, except for	Audio and video equipment manufacturing [334300]	39.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of speakers, including loudspeaker systems and loudspeakers [2008625000] and Manufacturing of other consumer audio and video equipment, including audio and video recorders and players (camcorders) [2008650000] in 2021 by this industry relative to its total output.
	Magnets, neodymium-iron-boron: robotics	lutetium. Lutetium's use in the medical and radiation detector	Other general purpose machinery manufacturing [33399A]	9.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of industrial robots [2016650000] in 2021 by this industry relative to its total output.

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	Magnets, neodymium-iron-boron: light duty truck and utility vehicle electric motors	applications were based on import data from bills of lading (Trade Mining, 2025), with the remaining applications being split equally.	Light truck and utility vehicle manufacturing [336112]	19.1	Assessment was based on the percent of light truck and utility vehicles manufactured in the United States that were battery electric, hybrid or plug-in hybrid vehicles in 2023 (U.S. Environmental Protection Agency, 2024).
	Magnets, neodymium-iron-boron: automobile electric motors	For rare earth elements that find use in both automotive catalytic converters and magnets for electric vehicles overlaps, the categories were merged in the model and assumed to be connected to virtually all (99.9%) of Automobile manufacturing [336111] Light truck and utility vehicle manufacturing [336112] industries' output.	Automobile manufacturing [336111]	31.2	Assessment was based on the percent of automobiles in the United States that were battery electric, hybrid or plug-in hybrid vehicles in 2023 (U.S. Environmental Protection Agency, 2024).
	Magnets, neodymium-iron-boron: other electric motors		Motor and generator manufacturing [335312]	9.5	Assessment was based on the assumption that 10% of motors and generators used rare earth permanent magnets, 95% of which were based on neodymium-iron-boron magnets.
	Magnets, neodymium-iron-boron: energy saving		Air conditioning, refrigeration, and warm air heating equipment manufacturing [333415]	6.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of room air conditioners and dehumidifiers, excluding portable dehumidifiers [2007325000] and Manufacturing of unitary air conditioners, excluding air source heat pumps [2038825000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 23%. This factor represents the share of all air conditioner units that use neodymium-iron boron magnets (Roskill Information Services Ltd., 2020a).
	Magnets, neodymium-iron-boron: other, medical	Industry connections were assumed to be the same across all rare earth elements, unless specifically identified.	Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of magnetic resonance imaging equipment (MRI) [2018000003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 14%, which represents the share of low-field strength MRI global market share in 2024 (Grand View Research, 2025b) multiplied by an assumed

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					95% market share for neodymium-iron-boron magnets.
	Magnets, neodymium-iron-boron: Other, guided missiles		Guided missile and space vehicle manufacturing [336414]	52.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of complete guided missiles [2012400000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 75%, which was the assumed market share of neodymium-iron-boron magnets.
	Magnets, neodymium-iron-boron: Other, search, detection, and navigation instruments		Search, detection, and navigation instruments manufacturing [334511]	5.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electronic warfare countermeasures equipment (jamming, communications, and radar) [2017500033], Manufacturing of gyroscopes [2017475012], Manufacturing of acceleration indicators, rate-of-climb and angle-of-attack indicators, and artificial horizon flight instruments [2017475006], Manufacturing of airborne navigational systems, inertial navigation systems [2017500057], Manufacturing of search, detection, and acquisition radar systems and equipment, airborne and missile/space [2017500009], Manufacturing of other search, detection, and acquisition radar systems and equipment [2017500012], Manufacturing of tracking radar systems and equipment (fire control, bombing, bombing-navigational radar, aircraft and missile tracking radar, etc.) [2017500015], Manufacturing of sonar search, detection, tracking, and communication systems and equipment guidance, including ASM (sonar telephone, depth finding, hydrophones mapping, sonobuoys, etc.) [2017500021] in 2017 by this industry relative to its

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					total output. The result was then multiplied by a factor of 25%, which was the assumed market share of neodymium-iron-boron magnets.
	Magnets, samarium-cobalt: Motors and generators		Motor and generator manufacturing [335312]	0.5	Assessment assumed that 10% of motors and generators used rare earth permanent magnets, 5% of which were based on samarium-cobalt magnets.
	Magnets, samarium-cobalt: Guided missiles		Guided missile and space vehicle manufacturing [336414]	17.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of complete guided missiles [2012400000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 25%, which was the assumed share for samarium-cobalt magnets.
	Magnets, samarium-cobalt: electromedical		Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.05	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of magnetic resonance imaging equipment (MRI) [2018000003] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 0.75%, which represents the share of low-field strength MRI global market share in 2024 (Grand View Research, 2025b), multiplied by an assumed 5% market share for samarium-cobalt magnets.
	Magnets, samarium-cobalt: Search, detection, and navigation instruments		Search, detection, and navigation instruments manufacturing [334511]	17.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electronic warfare countermeasures equipment (jamming, communications, and radar) [2017500033], Manufacturing of gyroscopes [2017475012], Manufacturing of acceleration indicators, rate-of-climb and angle-of-attack indicators, and artificial horizon flight instruments [2017475006], Manufacturing of airborne navigational systems, inertial navigation systems [2017500057], Manufacturing of search, detection,

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					and acquisition radar systems and equipment, airborne and missile/space [2017500009], Manufacturing of other search, detection, and acquisition radar systems and equipment [2017500012], Manufacturing of tracking radar systems and equipment (fire control, bombing, bombing-navigational radar, aircraft and missile tracking radar, etc.) [2017500015], Manufacturing of sonar search, detection, tracking, and communication systems and equipment guidance, including ASM (sonar telephone, depth finding, hydrophones mapping, sonobuoys, etc.) [2017500021] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 75%, which was the assumed market share of samarium-cobalt magnets.
	Optical glass		Optical instrument and lens manufacturing [333314]	6.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of binoculars and astronomical instruments [2018600003], Manufacturing of parts and accessories for binoculars and astronomical instruments [2045215000], Manufacturing of miscellaneous unmounted lenses for optical instruments and lenses [2018600015], Manufacturing of miscellaneous mounted lenses for optical instruments and lenses [2018600018] in 2017 by this industry relative to its total output.
	Phosphors (excluding erbium, holmium, thulium, and ytterbium)		Electric lamp bulb and part manufacturing [335110]	66.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electric lamp bulbs and tubes (including sealed beam lamp bulbs) [2051400000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 80%. This factor represents the approximate

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					percent of U.S. lamp shipments that were compact fluorescent or light-emitting diode in 2022 (National Electrical Manufacturers Association, 2023).
	Phosphors (erbium)		Semiconductor and related device manufacturing [334413]	0.02	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Phosphors (holmium)		Semiconductor and related device manufacturing [334413]	0.02	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Phosphors (thulium)		Semiconductor and related device manufacturing [334413]	0.82	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Phosphors (ytterbium)		Semiconductor and related device manufacturing [334413]	0.03	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Pigments		Synthetic dye and pigment manufacturing [325130]	4.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of white extender pigments (including barytes, blanc fixe, and whiting), ceramic color pigments, and all other inorganic pigments [2024375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 20%. This factor represents the approximate share of other inorganic pigments that were ceramic color pigments based on

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					data from the 1997 Economic Census for years 1992 and 1997 (U.S. Census Bureau, 1999).
	Polishing		Glass and glass product manufacturing [327200]	10.7	Rare earth elements use in polishing is mainly for glass: flat glass, optical glass, and liquid crystal displays (Roskill Information Services Ltd., 2021a). Given that the latter two uses already have their own application categories, the assessment was based on the value of shipments of the following NAPCS code: Manufacturing of flat glass (float, sheet, and plate process) [2026050000] in 2021 by this industry relative to its total output.
	Steel		Iron and steel mills and ferroalloy manufacturing [331110]	0.7	The total quantity of rare earth consumption in steels was divided by 97% to approximate the total quantity that of mischmetal that would have been used (assuming 3% of the content was iron and other impurities). The result was then divided by ratio of mischmetal added to steel, which was assumed to be the geometric mean of the reported 0.3-1.0 kg of rare earths per metric ton of steel (Roskill Information Services Ltd., 2021a) and then divided by the total raw steel production in the United States in 2023 (U.S. Geological Survey, 2025a).
	Cerium's other application: water treatment		All other chemical product and preparation manufacturing [3259A0]	0.07	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Dysprosium's other applications: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.005	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 0.1%. This factor was estimated based on the market share

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					of solid-state lasers (Parkhi, 2020) and an estimated proportion of solid-state lasers that may have used dysprosium (Global Market Insights, 2025b).
	Dysprosium's other applications: nuclear control rods		Electric power generation, transmission, and distribution [221100]	0.06	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Dysprosium's other applications: transducer		Other electronic component manufacturing [33441A]	2.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of transducers, electroacoustic (sonar, ultrasonic, vibration, etc.) [2033850003] in 2017 by this industry relative to its total output.
	Erbium's other application: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.14	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 2.2%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and the proportion of solid-state lasers that may have used erbium (Global Market Insights, 2025b).
	Europium's other applications: medical		Medical and diagnostic laboratories [621500]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Europium's other applications: nuclear control rods		Electric power generation, transmission, and distribution [221100]	0.03	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.

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	Europium's other applications: semiconductors		Semiconductor and related device manufacturing [334413]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Gadolinium's other applications: medical		Medical and diagnostic laboratories [621500]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Gadolinium's other applications: nuclear control rods		Electric power generation, transmission, and distribution [221100]	0.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Gadolinium's other applications: crystals		Other electronic component manufacturing [33441A]	1.4	Assessment was based on the total value of gadolinium-gallium garnet multiplied by 35% market share for North America (Verified Market Reports, 2025g) as a percent of total industry output in 2023.
	Holmium's other applications: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.01	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 0.17%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and an estimated proportion of solid-state lasers that may have used erbium (Global Market Insights, 2025b).
	Holmium's other applications: nuclear control rods		Electric power generation, transmission, and distribution [221100]	0.05	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.

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	Holmium's other applications: glass		Glass and glass product manufacturing [327200]	0.008	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Holmium's other applications: catalysts		Other basic inorganic chemical manufacturing [325180]	0.003	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Lanthanum's other application: water treatment		All other chemical product and preparation manufacturing [3259A0]	0.03	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Lutetium's other applications: medical		Electromedical and electrotherapeutic apparatus manufacturing [334510]	0.6	Assessment was based on the value of U.S. PET scanners market (Grand View Research, 2022e) as a percent of this industry's total output, multiplied by the approximate share (36%) of detectors based on lutetium oxyorthosilicate (Future Markets Insights, 2016).
	Lutetium's other applications: radiation detectors		Watch, clock, and other measuring and controlling device manufacturing [33451A]	0.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nuclear radiation detection and monitoring instruments [2017550000] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 8.6%. This factor represents the share of U.S. radiation detectors revenues based on scintillators in 2023 (Grand View Research, 2014) multiplied by the share of global scintillators that use lutetium (Astute Analytica, 2024).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Lutetium's other applications: petroleum refining		Petroleum refineries [324110]	0.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Lutetium's other applications: electronics		Semiconductor and related device manufacturing [334413]	1.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Lutetium's other applications: catalysts		Other basic organic chemical manufacturing [325190]	0.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Neodymium's other application: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 4.8%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and the proportion of solid-state lasers that may have used neodymium (Global Market Insights, 2025b).
	Praseodymium's other application: catalyst		Other basic inorganic chemical manufacturing [325180]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Samarium's other applications: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.005	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					The result was then multiplied by a factor of 0.09%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and an estimate proportion of solid-state lasers that may have used samarium (Global Market Insights, 2025b).
	Samarium's other applications: nuclear control rods		Electric power generation, transmission, and distribution [221100]	0.002	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Samarium's other applications: catalysts		Other basic inorganic chemical manufacturing [325180]	0.0001	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Terbium's other applications: transducer		Other electronic component manufacturing [33441A]	2.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of transducers, electroacoustic (sonar, ultrasonic, vibration, etc.) [2033850003] in 2017 by this industry relative to its total output.
	Terbium's other applications: semiconductors		Semiconductor and related device manufacturing [334413]	0.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Terbium's other applications: medical		Medical and diagnostic laboratories [621500]	0.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Thulium's other applications: lasers		All other miscellaneous electrical equipment and	0.01	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000]

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
			component manufacturing [335999]		in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 0.09%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and an estimate proportion of solid-state lasers that may have used thulium (Global Market Insights, 2025b).
	Ytterbium's other applications: stainless steel		Iron and steel mills and ferroalloy manufacturing [331110]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Ytterbium's other applications: catalysts		Plastics material and resin manufacturing [325211]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Ytterbium's other applications: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.02	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 0.3%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and an estimate proportion of solid-state lasers that may have used ytterbium (Global Market Insights, 2025b).
	Yttrium's other applications: lasers		All other miscellaneous electrical equipment and component manufacturing [335999]	0.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of laser sources, including nondiode and diode [2034025000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 8%. This factor was estimated based on the market share of solid-state lasers (Parkhi, 2020) and the proportion of

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					solid-state lasers that may have used ytterbium (Global Market Insights, 2025b)
	Yttrium's other application: yttrium ferrite garnet		Other electronic component manufacturing [33441A]	1.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of ferrite, including yttrium garnets, microwave components (circulators, isolators, phase shifters, attenuators, equalizers, limiters, mixers, etc.) [2033900003] in 2017 by this industry relative to its total output.
Rhenium	Superalloys: aerospace	The proportions of rhenium's use in the United States were assumed to be 80% for superalloys and 15% for catalysts. The remaining 5% was split equally among the identified applications.	Aircraft engine and engine parts manufacturing [336412]	86.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output.
	Superalloys: industrial turbines	Rhenium's use in superalloys was split 80%-20% between aerospace and industrial turbines, respectively.	Turbine and turbine generator set units manufacturing [333611]	57.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output.
	Petroleum catalyst		Petroleum refineries [324110]	25.0	Assessment was based on the U.S. refinery catalytic reforming downstream charge capacity relative to total downstream charge capacity in 2023 (U.S. Energy Information Administration, 2024b).
	Semiconductor equipment (infrared)		Semiconductor machinery manufacturing [333242]	0.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	heating lamps and heater filaments)				all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Thermocouples		Industrial process variable instruments manufacturing [334513]	0.34	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other temperature measuring instruments [2017625033], Manufacturing of primary temperature sensors, excluding aircraft types, thermocouples [2017625036], Manufacturing of electrical and electronic temperature measuring instruments [2017625031] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 4.1%. This factor represents the value of the global tungsten-rhenium thermocouple wire market (Verified Market Reports, 2025m) as a percent of the total thermocouple market (Dhapte, 2025).
	Semiconductors		Semiconductor and related device manufacturing [334413]	0.04	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Other electronics including thin-film resistors		Other electronic component manufacturing [33441A]	0.09	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Rocket nozzle and combustion chambers		Propulsion units and parts for space vehicles and guided missiles [33641A]	3.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					(except aluminum) smelting and refining [331410] industry.
Rhodium	Automotive: catalytic converters for light truck and utility vehicles	The proportions of rhodium's use in the United States by application were obtained from CPM Group (2024a).	Light truck and utility vehicle manufacturing [336112]	97.3	Assessment was based on the percent of light duty trucks and utility vehicles manufactured in the United States that use catalytic converters (meaning all those that were not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Automotive: catalytic converters for automobiles		Automobile manufacturing [336111]	78.3	Assessment was based on the percent of automobiles manufactured in the United States that use catalytic converters (meaning all those that were not battery electric vehicles) (U.S. Environmental Protection Agency, 2024).
	Automotive: catalytic converters for heavy duty vehicles	The proportion of rhodium's use in automotive applications was split 90%-10% between light duty vehicle manufacturing and heavy-duty truck manufacturing, respectively. Light duty vehicle manufacturing was split between light duty truck and utility vehicle manufacturing and automobile manufacturing based on 2023 industry output.	Heavy duty truck manufacturing [336120]	98.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of buses, complete, including military (excluding trolley buses) [2011900000], Manufacturing of heavy-duty trucks, including heavy-duty truck, tractor, and bus chassis [2011910000], and Manufacturing of firefighting vehicles and other heavy trucks, complete [2011925000] in 2021 by this industry relative to its total output.
	Electrical & electronics: thermocouples		Industrial process variable instruments manufacturing [334513]	0.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other temperature measuring instruments [2017625033], Manufacturing of primary temperature sensors, excluding aircraft types, thermocouples [2017625036], and Manufacturing of electrical and electronic temperature measuring instruments [2017625031] in 2017 relative to the industry's total output. The result was then multiplied by a factor of 7.9%. This factor represents the global market share of precious metal thermocouples (Dhapté, 2025; Market Reports World, 2022).
		All other applications were split equally among			

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Glass manufacturing equipment	their associated BEA industries.	Glass and glass product manufacturing [327200]	6.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other glass fiber, textile-type (including yarn, strand, staple yarn, sliver, roving, chopped strand, and milled glass fiber) [2020575000] and Manufacturing of glass fiber mat, textile-type [2021225000] in 2021 by this industry relative to its total output.
	Chemical: acetic acid synthesis (Monsanto process)		Other basic organic chemical manufacturing [325190]	1.2	Assessment was based on an estimated production capacity of rhodium-based U.S. acetic acid production capacity (~2,330 thousand metric tons, (ICIS, 2019)) and a unit value for acetic acid of \$740 per metric ton (average price in North America in June 2023) (ChemAnalyst, 2024a) by this industry relative to its total output in 2023.
	Chemical: n-aldehydes oxo synthesis (hydroformylation)		Other basic organic chemical manufacturing [325190]	1.2	Assessment was based on the geomean of the production range of 1-5 billion pounds of butanal as reported by the U.S. Environmental Protection Agency (2022) for year 2019, an assumed price of butanal of \$2 per kg in 2022, and a 75% market share of butanal synthesis based on rhodium catalysts (Malewar, 2020).
	Chemical: acetic anhydride synthesis (Hoechst/Halcon process)		Other basic organic chemical manufacturing [325190]	0.3	Assessment was based on the geomean of the production range of 500-750 million pounds of acetic anhydride reported in the U.S. Environmental Protection Agency (2022) for year 2019 and an assumed price of acetic anhydride of \$1.61 per kg for North America in September 2022 (ChemAnalyst, 2024b).
	Chemical: hydrogenation (Wilkinson's catalyst)		Other basic organic chemical manufacturing [325190]	1.0	The rhodium-based Wilkinson's catalyst is used mainly used in the selective hydrogenation of alkenes and alkynes. A wide variety of chemicals can be made using this catalyst include carbene (2-Methyl-5-(prop-1-en-2-yl)cyclohex-2-en-1-one) and

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					L-DOPA (L-3,4-dihydroxyphenylalanine) used to treat Parkinson's disease. Given the lack of information, it was assumed that 1% of this industry's value was produced using this catalyst.
	Chemical: nitric acid synthesis		Fertilizer manufacturing [325310]	1.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nitric acid [2034625003] in 2017 by this industry relative to its total output.
	Other		Jewelry and silverware manufacturing [339910]	1.6	Assessment was based on the value of the calculated apparent consumption of this commodity by this industry in 2023 multiplied by the ratio of revenue generated by this industry to the total material expenditure of this industry in 2017 based on from data reported in the Economic Census (U.S. Census Bureau, 2023), relative to the total output of this industry in 2023.
Ruthenium	Chemical: ammonia synthesis	The proportions of ruthenium's use by application were obtained from Cowley (2024). These data pertain to global application fractions but were assumed applicable to the United States.	Fertilizer manufacturing [325310]	0.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of synthetic ammonia for fertilizer use [2034625006] and Manufacturing of anhydrous synthetic ammonia for other uses [2034625009] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 5%. This factor represents the approximate percent of ammonia produced using ruthenium catalysts (Smith and Torrente-Murciano, 2021).
	Chemical: acetic acid synthesis (Cativa™ process)	The proportion of ruthenium's in the "chemical" application was split equally among the associated BEA industries. Similarly, the	Other basic organic chemical manufacturing [325190]	0.3	Assessment was based on an estimated production capacity of ruthenium-promoted U.S. acetic acid production capacity (~600 thousand metric tons) (ICIS, 2019) and a unit value for acetic acid of \$740 per metric ton (average price in North America in June 2023) (ChemAnalyst, 2024a) relative to the industry's total output in 2023.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Chemical: other organic compound synthesis	proportion of ruthenium's use in the "other" application category was split equally among the associated BEA industries. The proportion of ruthenium's use in the "electrical" and "electrochemical" applications was split among the associated BEA industries based on additional information noted by Cowley (2024).	Other basic organic chemical manufacturing [325190]	1.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other synthetic organic chemicals [2025050000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 10%. This factor represents an assumed percent of other synthetic organic chemicals that were manufactured using ruthenium catalysts. This includes oxidation, hydrogenation, olefin metathesis, and other chemical syntheses.
	Electrical: hard disk drives		Computer storage device manufacturing [334112]	17.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of disk subsystems and disk arrays for multiuser computer systems [2011625003] and Manufacturing of disk drives (all sizes) [2011625006] in 2017 by this industry relative to its total output. Mass production of hard disk drives that use heat-assisted magnetic recording technology that does not use ruthenium, had not entered mass production during the year of the analysis.
	Electrical: resistor paste		Other electronic component manufacturing [33441A]	2.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of resistors for electronic circuitry [2033750000] in 2021 by this industry relative to its total output.
	Electrical: semiconductor interconnects		Semiconductor and related device manufacturing [334413]	0.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of microprocessors [2033575000], Manufacturing of memory [2033600000], Manufacturing of other semiconductor devices, including semiconductor parts such as chips, wafers, and heat sinks [2033700000], Manufacturing of other integrated circuit packages [2033625000] in 2021 by this industry relative to its total output. The result was

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					then multiplied by a factor of 1%. This factor represents the percent of world sputtering target market based on ruthenium in 2018 (Roskill Information Services Ltd., 2020c).
	Electrochemical: chlor-alkali		Other Basic Inorganic Chemical Manufacturing [325180]	12.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of chlorine, compressed or liquefied [2024625000] and Manufacturing of sodium hydroxide (caustic soda) [2024650000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 95.6%. This factor represents the percent of 2022 U.S. chlor-alkali industry capacity that use membrane or diaphragm cells, which use ruthenium (Kreuz and others, 2022).
	Electrochemical: treatment of ballast water		Ship building and repairing [336611]	1.6	Assessment was based on the value of the global market for ballast water treatment systems in 2022, (Maximize Market Research, 2023a) multiplied by the North American share of that market (55%), (Maximize Market Research, 2023a), an assumed 80% share of the North American market for the United States, and a 37% share ballast water treatment systems for the ruthenium-iridium based electrolytic chlorination systems. The result was divided by the total output of the industry in 2023 (Heraeus Precious Metals and SFA (Oxford) Ltd., 2020).
	Electrochemical: proton exchange membrane		Industrial gas manufacturing [325120]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of argon and hydrogen [2024200000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 1.05%. This factor accounts for the share of this NAPCS code that was for the manufacture of hydrogen (roughly 73%, (U.S.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					Census Bureau, 2004d)), the percent of hydrogen produced by electrolyzers (roughly 7%) (U.S. Energy Information Administration, 2024a), and the percent of electrolyzers that were based on proton membrane exchange (roughly 20%) (Hydrogen Council and McKinsey & Company, 2023).
	Other: corrosion-resistance alloys for offshore oil and geothermal production		Plate work and fabricated structural product manufacturing [332310]	0.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fabricated structural iron and steel for offshore oil and gas platforms [2035100006] in 2017 by this industry relative to its total output.
	Other: jewelry alloys		Jewelry and silverware manufacturing [339910]	0.1	Assessment was based on the value of the calculated apparent consumption of this commodity by this industry in 2023 multiplied by the ratio of revenue generated by this industry to the total material expenditure of this industry in 2017 based on from data reported in the Economic Census (U.S. Census Bureau, 2023), relative to the total output of this industry in 2023.
	Other: dental alloys		Dental equipment and supplies manufacturing [339114]	0.5	Assessment was based on the value of the calculated apparent consumption of this commodity by this industry in 2023 multiplied by the ratio of revenue generated by this industry to the total material expenditure of this industry in 2017 based on from data reported in the Economic Census (U.S. Census Bureau, 2023), relative to the total output of this industry in 2023.
	Other: carbides		Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	0.2	Assessment was based on the value of the calculated apparent consumption of this commodity by this industry in 2023 multiplied by the ratio of revenue generated by NAICS industries 333515 and 333519 to the total material expenditures of these two industries in 2017 based on from data reported

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					in the Economic Census (U.S. Census Bureau, 2023), relative to the total output of this industry in 2023.
Selenium	Metallurgy: steel additive	The proportions of selenium's use by application category (metallurgy; glass, electronics and semiconductors; chemicals and pharmaceuticals; and other) in the United States were obtained from Mordor Intelligence (2025c). Selenium's use in the reported application categories were disaggregated into each sub-application based on the portion of each associated industry's output that used selenium as a percent of the portion of the output of all associated industries that used selenium within the application category. This approach was taken for all application	Iron and steel mills and ferroalloy manufacturing [331110]	0.2	Selenium can be an additive in certain steels (for example, 303Se, 430Se, and 416Se). Assessment was based on the production of these steels (American Iron and Steel Institute, 2023b) multiplied by an assumed price of 430 stainless steel (Argus Media Group, 2024) as a percent of the total output of this industry in 2023. This percentage may be an overestimation given that some of the reported steels may not incorporate selenium.
	Metallurgy: copper alloys		Copper rolling, drawing, extruding and alloying [331420]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Metallurgy: lead alloys		Storage battery manufacturing [335911]	0.04	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Glass: flat glass		Glass and glass product manufacturing [327200]	7.7	Assessment was based on the quantity of selenium consumed in this application multiplied by 5% (given that up to 95% of selenium added may be volatilize during processing) divided by a reported usage of 1-2 ppm selenium content of flint glass (Timmer and others, 2010) as a percent of the total glass output of the United States (Eisenhower and Johnson, 1999).

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	Glass: lenses	categories except for the metallurgical application, which was split equally among the sub-applications.	Optical instrument and lens manufacturing [333314]	3.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of all other miscellaneous optical instruments and lenses (including binoculars and astronomical instruments) [2018600000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 7.7%. This factor represents the value of the global sintered zinc selenide optical lens market (Custom Market Insights, 2024) as a percent of the overall global optical lens market (Fortune Business Insights, 2023).
	Electronics and semiconductors: photovoltaic cells		Semiconductor and related device manufacturing [334413]	0.003	Assessment was based on the nameplate capacity of the leading copper-indium-gallium-(de)selenide solar cells producer in the United States (Ascent Solar Technologies Inc., 2024) multiplied by the average U.S. solar photovoltaics module value in 2023 (Feldman and others, 2024) divided by the total industry output.
	Electronics and semiconductors: photodetectors		Semiconductor and related device manufacturing [334413]	0.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other light-sensitive and light-emitting devices [2033700012] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 21.4%, which represents an estimated share for selenium based on the value global amorphous selenium photodetectors market (Sharma, 2025a) as a percent of the global photodetectors market (Sharma, 2025b) in 2024.
	Electronics and semiconductors: quantum dots		Semiconductor and related device manufacturing [334413]	0.7	Assessment was based on the value of the North American cadmium selenium quantum dot market (Maximize Market Research, 2025b), multiplied by an assumed 85% US. share of the North American market, as a percent of this industry's total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Chemicals and pharmaceuticals: selenium dioxide		Other basic inorganic chemical manufacturing [325180]	0.2	Assessment was based on the value of global selenium dioxide market (Verified Market Research, 2025a) as a percent of the value of the global "other inorganic chemical market" (The Business Research Company, 2025)
	Chemicals and pharmaceuticals: Dyes and pigments		Synthetic dye and pigment manufacturing [325130]	1.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of white extender pigments (including barytes, blanc fixe, and whiting), ceramic color pigments, and all other inorganic pigments [2024375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 8.7%, which represents the global value of cadmium pigments (in which selenium is used) as a percent of all other inorganic pigments excluding titanium dioxide, iron oxide, and chromium (Global Market Insights, 2024a)
	Chemicals and pharmaceuticals: dietary supplements		Medicinal and botanical manufacturing [325411]	0.001	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of pharmaceutical preparations, vitamin, nutrient, and hematinic preparations, for human use [2010300000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 2.7%, which represents the share of the North American selenium dietary supplements market (Wise Guy Reports, 2024b) as a percent of the total North American dietary supplements market (Research and Markets, 2025).
	Chemicals and pharmaceuticals: anti-dandruff shampoo		Toilet preparation manufacturing [325620]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of hair preparations (including shampoos) [2010525000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 1.5%, which represents the value of the global selenium sulfide

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					shampoo market (Archive Market Research, 2025) as a percent of the value of the entire global shampoo market (Patel, 2024).
	Other: Animal feed		Other animal food manufacturing [311119]	69.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of chicken and turkey feed, supplements, concentrates, and premixes [2034450000], Manufacturing of complete dairy cattle feed, supplements, concentrates, and premixes [2034475000], Manufacturing of complete swine feed, supplements, concentrates, and premixes [2034500000], Manufacturing of complete beef cattle feed, supplements, concentrates, and premixes [2034525000] in 2021 by this industry relative to its total output.
	Other: Fertilizer additive		Fertilizer manufacturing [325310]	5.6	Assessment was based on the value of the U.S. micronutrients market as a percent of the value all fertilizers (Mordor Intelligence, 2021b).
Silicon ferroalloys	Iron and steel	Ferrosilicon's use in the United States was assumed to all be used by this BEA industry.	Iron and steel mills and ferroalloy manufacturing [331110]	61.8	Assessment was based on the value of ferrosilicon-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of ferrosilicon-containing steel produced, the quantity of ferrosilicon consumed in various types of steel was divided by the estimated elemental contents of silicon-containing steels (Roskill Information Services Ltd., 2019c) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).
Silicon metal	Aluminum	The proportions of silicon metal's use in the United States by application	Secondary smelting and alloying of aluminum [331314]	89.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		were obtained from the U.S. Geological Survey (2025b), some of which were withheld to avoid releasing company proprietary information but used in this analysis. Reported silicon metal use in steels is assumed to be metallurgical-grade silicon and allocated to with the ferrosilicon commodity.			aluminum ingot, including billet [2026995000] in 2021 by this industry relative to its total output.
	Semiconductors and solar photovoltaics		Semiconductor and related device manufacturing [334413]	85.2	Assessment was based on subtracting the value of the U.S. compound semiconductors market in 2023 (Grand View Research, 2024f) from the total output of this industry as a percent of this industry's output.
	Silicones		Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	9.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of silicone elastomers [2025550000] in 2021 by this industry relative to its total output.
Silver	Batteries, primary	The proportions of silver's use in the United States by application category were obtained from CPM Group (2024b).	Primary battery manufacturing [335912]	3.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of primary batteries, excluding lead acid [2010950000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 4.2%, which represented the approximate percent of global primary battery that used silver (Market.Us, 2025b) in 2024.
	Biocides	Silver's use in solar photovoltaics was estimated based on the quantity (in gigawatts) of crystalline-silicon photovoltaic modules manufactured in the United States in 2023 (Feldman and others, 2024) multiplied by the global quantity of silver demand for solar photovoltaics divided by	Surgical appliance and supplies manufacturing [339113]	1.6	Assessment was based on the value of the North American silver wound dressing market as a percent of this industry's total output (Grand View Research, 2024d).
	Brazing alloys and solders		Coating, engraving, heat treating and allied activities [332800]	2.7	Assessment was based on the value of shipments of the following NAPCS code: Heat treating of metal for the trade (heat treating, pickling, annealing, brazing, shot peening, tempering, etc.) [2053450000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 15%, which was silver's share of global braze alloys in 2023 (Maximize Market Research, 2023b).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Catalyst	the total quantity of photovoltaics installed (The Silver Institute and Metals Focus, 2025). This quantity of silver was assumed to be a component of the reported silver use in electrical and electronic components.	Other basic organic chemical manufacturing [325190]	2.9	Assessment was based on value of ethylene oxide manufactured in the United States in 2018 (Swift and others, 2019).
	Dental equipment and supplies		Dental equipment and supplies manufacturing [339114]	2.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 24%. This factor represents the approximate market share of dental metals that were based on silver dental alloys in 2022 (KBV Research, 2024b).
	Dental laboratories	Silver's remaining use in the electrical & electronics application was split based the expenditure of the associated BEA industries on gold and other precious metals (Material code: 33141911) reported in 2012 Economic Census (U.S. Census Bureau, 2012a).	Dental laboratories [339116]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 24%. This factor represents the approximate market share of dental metals that were based on silver dental alloys in 2022 (KBV Research, 2024b).
	Electrical & electronics: bare printed circuit	Silver's use in dental application was estimated based on an estimated number of annual fillings in the United States (175 million),(King, 2011) the	Other electronic component manufacturing [33441A]	1.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of bare printed circuit boards [2014930000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 12%, which represents the approximate share of global printed circuit board finishes that used silver immersion in 2016 (Shah, 2018).
	Electrical & electronics: integrated circuit packages		Semiconductor and related device manufacturing [334413]	11.0	Assessment was based on the percent of the global bonding wire market that used silver in 2017 (Lau and Lam, 2020).

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	Electrical & electronics: other electronic components	percent of fillings that were based on silver amalgam (4.1% in 2023) (Lamsal and others, 2024) and an assumed silver content per filling of 0.17 grams.	Other electronic component manufacturing [33441A]	7.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electronic connectors, including parts [2033800000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 45%, which was the estimated market share for silver-based contacts (Data Horizon Research, 2025).
	Electrical & electronics: printed circuit assemblies	The proportion of silver's use in the dental application was split proportionally based of the value of shipments of the Manufacturing of dental metals, artificial teeth not customized for individual application, and other dental laboratory supplies [2045975000] NAPCS code reported by those two associated BEA industries.	Printed circuit assembly (electronic assembly) manufacturing [334418]	10.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Jewelry	This quantity of silver was assumed to be a component of the reported silver use in "miscellaneous" application category.	Jewelry and silverware manufacturing [339910]	18.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of jewelry and personal goods (excluding costume), all other precious metals and types, including silver and silver-clad jewelry; jewelry made of precious stones, semi-precious stones, or pearls; and stamped metal coins [2005625000], Manufacturing of jewelers' findings and materials, precious metal (excluding gold, platinum, and silver plated to nonprecious metal) [2034375000] in 2021 by this industry relative to its total output.
	Mirrors	The remaining use of silver under the "miscellaneous"	Glass and glass product manufacturing [327200]	0.5	Assessment was based on the value of the North American silver mirror market in 2024 as a percent of this industry's output (Verified Market Reports, 2025k).
	Photography		All other chemical product and preparation manufacturing [3259A0]	5.0	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of photographic presensitized printing plates (unexposed), phototypesetting and image-setting film, sensitized photographic paper and cloth, silver-

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		application category was assumed to be for electroplating.			halide-type (excluding X-ray) [2046400000] in 2021 by this industry relative to its total output.
	Silverplate and sterling ware	Silver's use in official coins and other investment instruments was not connected to any BEA industry.	Jewelry and silverware manufacturing [339910]	2.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of silverware and hollowware made of precious solid or clad metal [2007600000], Manufacturing of hollowware, unplated, plated, and electroplated, precious and nonprecious metals, including baby goods, ecclesiastical ware, novelties, toiletware, and trophies [2007625000] in 2021 by this industry relative to its total output.
	Solar photovoltaic		Semiconductor and related device manufacturing [334413]	1.6	Assessment was based on the quantity of crystalline-silicon solar photovoltaics modules manufactured in the United States multiplied by the average U.S. solar photovoltaics module value in 2023 (Feldman and others, 2024) divided by the total industry output.
	Other		Coating, engraving, heat treating and allied activities [332800]	2.5	Assessment was based on the value of shipments of the following NAPCS code: Electroplating, plating, polishing, anodizing, and coloring [2053500000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 10%, which represented the percent of global electroplating market that was based on silver (Global Growth Insights, 2025a).
Strontium	Aluminum master alloy	The proportions of strontium's use in the United States by application category were obtained from estimates made by the U.S. Geological Survey (2024)	Secondary smelting and alloying of aluminum [331314]	0.02	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of aluminum and aluminum-base alloy powders, paste, and flakes [2026990000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 0.2%, which was the estimated share of strontium aluminum master alloy. This share was estimated by dividing the quantity of strontium used in aluminum strontium master alloy

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		The aggregated category of electrolytical zinc, master alloy, pigments and fillers and other applications, including glass" was between electrolytic zinc, master alloy, and glass based on information from the Chemical Data Reporting database (U.S. Environmental Protection Agency, 2022) with the remaining being allocated to paints and pigments.			application by an assumed strontium content of 10% (AMG Aluminum, 2024) and then by the total quantity of secondary aluminum alloys produced in the United States (U.S. Geological Survey, 2025b).
	Electrolytic zinc production, primary		Nonferrous metal (except aluminum) smelting and refining [331410]	3.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of refined primary unalloyed zinc slab and zinc-base alloy, including unalloyed dust [2027431000] in 2021 by this industry relative to its total output.
	Electrolytic zinc production, secondary		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	3.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of refined secondary alloyed and unalloyed zinc, including all ASTM-specification zinc [2027427000] in 2021 by this industry relative to its total output.
	Glass		Glass and glass product manufacturing [327200]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Magnetic alloys		Clay product and refractory manufacturing [327100]	0.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of all wet and dry process voltage porcelain products and components, including steatite electrical products and other ceramic electrical products and components for electronic applications [2034100000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 9.3%, the percent of this product category's output that was ceramic permanent magnets based on the 2002 Economic Census (U.S. Census Bureau, 2004a).
	Paints	Strontium's use in electrolytic zinc production was split between primary and secondary production based on the reported domestic production of primary and secondary smelter (U.S. Geological Survey, 2025b).	Paint and coating manufacturing [325510]	0.05	Assessment was based on the value of the global strontium chromate market (Market Research Intellect, 2025) multiplied by the North American

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					share of strontium in paints and coats (Transparency Market Research, 2018) divided the total industry output in 2023.
	Pigments		Synthetic dye and pigment manufacturing [325130]	0.6	Assessment was based on the value of the North America's share of the global strontium aluminum market multiplied an assumed 90% market share for the United States (Verified Market Research, 2025b).
	Pyrotechnics and signals		All other chemical product and preparation manufacturing [3259A0]	0.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fireworks and pyrotechnics, including flares, igniters (jet fuel or other), railroad torpedoes, toy pistol caps, etc. [2046700000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 42.9% (three-sevenths) given that three of the seven main colors of fireworks used strontium (U.S. Geological Survey, 2020b).
	Well drilling		Drilling oil and gas wells [213111]	0.04	Assessment was based on the value of shipments of the following NAPCS code: Drilling oil and gas wells, including drilling in, spudding in, or tailing in [1001625000] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 0.05%, which represents the estimated market share for strontium based on the ratio of celestite to barite used in the United States for well drilling.
Tantalum	Cemented carbides: Cutting tool, machine tool accessories, and industrial molds	The proportions of tantalum's use in the United States by application category were obtained from Padilla and Nassar (2023). These data pertain to year 2020.	Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	6.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of cutting tools (including broaches, reamers, hobs) and all other miscellaneous solid and tipped carbide cutting tools for machine tools and metalworking machinery, excluding tips and blanks [2050000000], Manufacturing of high-speed steel end and solid and tipped carbide end mills, non- and indexable-

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		<p>Tantalum's use in cemented carbides was split between two industries based on the reported consumption of tungsten carbide by those two industries in the 2012 Economic Census (U.S. Census Bureau, 2012b).</p> <p>Tantalum's use in superalloys was split into two applications based on data from on nickel-based superalloys reported by Eckard (2017), excluding superalloys used in nuclear reactors, industrial processes, oil and gas, and automotive.</p>			<p>inserted-blade-type, throwaway-insert-type, and all other miscellaneous milling cutters [2050025000], Manufacturing of carbon and high-speed steel shank and solid and tipped carbide twist drills, including masonry twist drill bits, gun drills, combined drills, countersinks, and counterbores [2050075000], Manufacturing of taps (excluding taps in threading sets and screw plates and inserted chaser types) and precision ground carbide indexable and throwaway inserts for machine tools and metalworking machinery [2050100000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 13.8%. This factor assumes that half of the non-tungsten carbide share of cutting tools are tantalum carbides (Market.U.S., 2025a).</p>
	Cemented carbides: special dies and tools		Special tool, die, jig, and fixture manufacturing [333514]	6.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of metalworking die and die sets [2016200000], Manufacturing of punches, die parts, and other special tooling [2016225000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 13.8%. This factor assumes that half of the non-tungsten carbide share of cutting tools are tantalum carbides (Market.U.S., 2025a).
	Chemical processing industry: high-temperature alloys		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	0.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of titanium and titanium-base alloy forging and extrusion, ingot and billet, and all other titanium and titanium-base alloy mill shapes (including sheet, plate, tubing, bar, etc.), excluding wire [2027400000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 5%, which was the

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					assumed market share of tantalum in titanium-based mill shapes.
	Chemical processing industry: Heat exchangers		Power boiler and heat exchanger manufacturing [332410]	1.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fabricated heat exchangers and steam condensers closed types (excluding nuclear applications) including bar and fin tube [2016375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 3%. This factor represents the share of tantalum in the U.S. shell and tube heat exchanger market (Grand View Research, 2024c).
	Electronics: Electrolytic capacitors		Other electronic component manufacturing [33441A]	1.2	Assessment was based on the value of the tantalum capacitor market (Research and Markets, 2024c) multiplied by the U.S. share of global tantalum used in capacitors (Project Blue, 2025g).
	Electronics: Hard disc drive (HDD) media		Manufacturing and reproducing magnetic and optical media [334610]	11.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of magnetic and optical recording media, including unrecorded disks and tapes [2046800000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 26.8%. This factor represents the global market share of optical storage media that contain tantalum (Deetman and others, 2018).
	Electronics: Semiconductors and resistors		Semiconductor and related device manufacturing [334413]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of diodes and rectifiers [2033675000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 39%. This factor represents the share of 2018 global sputtering target market that was based on tantalum (Roskill Information Services Ltd., 2020c).

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	Electronics: Wave filters		Other electronic component manufacturing [33441A]	2.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of crystals, filters, piezoelectric, and other related electronic devices (excluding microwave filters) [2033825000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 39%. This factor represents the share of 2018 global sputtering target market that was based on tantalum (Roskill Information Services Ltd., 2020c).
	Medical applications: Internal fixation devices and stents		Surgical and medical instrument manufacturing [339112]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of surgical and medical internal fixation devices (bone nails, plates, and screws, etc.) [2045800000], Manufacturing of stents [2045875031] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 2.25%. This factor represents the share of implants that were estimated to be based on tantalum, which was estimated multiplying the approximate market share of implants made of titanium (45%) (Grand View Research, 2023d) by the ratio of the quantity of tantalum to titanium (5%) used in this application.
	Optical glass		Ophthalmic goods manufacturing [339115]	0.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of ophthalmic focal lenses, prescription, ground, excluding retailing prescription eyeglasses in combination with the grinding of the eyeglass lenses to order on the premises [2034350000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 2%. This factor represents the market share of tantalum in vision correction lenses (Deetman and others, 2018).

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	Research & development		Scientific research and development services [541700]	0.4	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Superalloys: aerospace		Aircraft engine and engine parts manufacturing [336412]	71.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 82.6%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: industrial turbines		Turbine and turbine generator set units manufacturing [333611]	39.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 69.1%. This factor represented the percent of superalloys that were estimated to be nickel-based (and thus niobium-containing) for this application in 2016 (Eckard, 2017).

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Tellurium	Metallurgy	<p>The proportions of tellurium's use by application in the United States were estimated based on global demand by application reported by Mordor Intelligence (2025d).</p> <p>The undifferentiated other application category was split equally into sub-applications.</p>	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Photovoltaics		Semiconductor and related device manufacturing [334413]	1.5	Assessment was based on the quantity of thin-film solar photovoltaics produced in the United States in 2023 less the estimated amount that was copper-indium-gallium-(di)selenide solar cells multiplied by the average U.S. solar photovoltaics module value in 2023 (Feldman and others, 2024) divided by the total industry output.
	Thermoelectric devices		Semiconductor and related device manufacturing [334413]	0.2	Assessment was based on the North American share of the global bismuth telluride market as a percent of this industry's output in 2023 (Verified Market Reports, 2025b).
	Other: rubber vulcanizing		Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	0.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of styrene-butadiene rubber (SBR), excluding latex [2025425000], Manufacturing of styrene-butadiene rubber (SBR), latex [2025450000], Manufacturing of butyl, polychloroprene, and stereo polyisoprene elastomers, and nitrile rubber, including latex [2025475000] in 2019 by this industry relative to its total output. The result was then multiplied by a factor of 4%, which represents the estimated share of rubber vulcanization that was used on tellurium diethyldithiocarbamate based on the value of the global market for tellurium diethyldithiocarbamate (Global Growth Insights, 2025b) as a percent of the entire rubber accelerator market (Business Research Insights, 2025b).

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	Other: blasting caps		All other chemical product and preparation manufacturing [3259A0]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of explosives and blasting accessories [2041750000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 7.9%, which represents the estimate share of explosives that use electronic blasting caps based on the value of the global market for electronic blasting caps (Verified Market Reports, 2025e) as a percent of the value of the global industrial explosives market (360iResearch, 2025).
	Other: lenses		Optical instrument and lens manufacturing [333314]	39.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of sighting, tracking, and fire-control equipment, optical-type [2018575000], Manufacturing of sighting and tracking laser systems [2018575009], Manufacturing of night vision goggles and equipment [2018575012], Manufacturing of miscellaneous filters for optical instruments and lenses [2018600012] in 2017 by this industry relative to its total output.
Tin	Alloys	The proportions of tin's use by application were obtained from the U.S. Geological Survey (2025b), some of which were aggregated to avoid releasing company proprietary information but used in this analysis at a more disaggregated level.	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	4.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other nonferrous metals and alloys, lead, tungsten, molybdenum, rolled, drawn, and extruded shapes (sheet, strip, pipe, tubing, traps, etc.), excluding wire [2027425000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 48.5%, which represents the remaining share of this output after the outputs associated with lead, tungsten, and molybdenum were removed based on the 2002 Economic Census (U.S. Census Bureau, 2004a).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Batteries, lead-acid	<p>Tin's use in chemical applications was disaggregated into sub-application based on data presented by Roskill Information Services Ltd. (2019d).</p> <p>The application category of "Miscellaneous metal forms" represents the sum of tin's use in babbitt, bar, tubes, foil, type, and white metal.</p>	Storage battery manufacturing [335911]	49.2	Assessment was based on the average value of shipments of the following NAPCS codes: Manufacturing of storage batteries, lead-acid-type, BCI dimensional size group 8D (1.5 cu ft (.042 cu m) and smaller) [2030050000], Manufacturing of motive-power-type lead acid storage batteries, larger than BCI dimensional size group 8D (1.5 cu ft (.042 cu m)), including mining and industrial locomotive [2030075000], Manufacturing of all other lead acid storage batteries, larger than BCI dimensional size group 8D (1.6 cu ft (.042 cu m)), including communication and standby emergency [2030125000] in 2020 and 2021 relative to the total industry output in 2023.
	Chemicals: biocides	<p>Additionally, the quantity of tin used in lead-acid batteries, which was estimated based on the estimated ratio of global lead and tin used in lead-acid batteries, was added to the reported consumption.</p>	Pesticide and other agricultural chemical manufacturing [325320]	1.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Chemicals: brake pads		Motor vehicle steering, suspension component (except spring), and brake systems manufacturing [3363A0]	0.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other motor vehicle brake parts and assemblies, new [2042750000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 4.1%. this factor represents the approximate share of brake pads that use tin, which was estimated based on a noted volume of global tin used in brake pads (roughly 1000 metric tons) (Roskill Information Services Ltd., 2019d), a reported tin content of 3%, (Hulskotte and others, 2014) and a total mass of brake pads of approximately 814 thousand metric tons (McWilliams, 2018).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Chemicals: catalysts		Urethane and other foam product (except polystyrene) manufacturing [326150]	14.2	Assessment was based on the percent of the polyurethane produced by organometallic catalyst,(Grand View Research, 2024b) which were assumed to be dominated by tin.
	Chemicals: cement		Cement manufacturing [327310]	9.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of portland cement and other portland hydraulic cements (including oil well, white cement, blended cements, etc.), and masonry cement and cement clinker [2026400000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 10%, which was an assumed percent of cement additives based on tin given that tin has lost significant market share since its peak of 20% (Pearce and Wallace, 2015).
	Chemicals: ceramic pigments		Synthetic dye and pigment manufacturing [325130]	4.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of white extender pigments (including barytes, blanc fixe, and whiting), ceramic color pigments, and all other inorganic pigments [2024375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 19.1%. This factor represents the approximate share of ceramic color pigment based on the 1997 Economic Census (U.S. Census Bureau, 1999).
	Chemicals: electroplating		Coating, engraving, heat treating and allied activities [332800]	1.6	Assessment was based on the value of shipments of the following NAPCS code: Electroplating, plating, polishing, anodizing, and coloring [2053500000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 6.7%, which was the approximate fraction of the global electroplating market that was based on tin (Market.U.S., 2024a; Verified Market Reports, 2025).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Chemicals: flame retardants		All other chemical product and preparation manufacturing [3259A0]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Chemicals: glass		Glass and glass product manufacturing [327200]	2.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Chemicals: indium tin oxide		Other electronic component manufacturing [33441A]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of all other specialized electronic hardware [2033925018] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 4.8%. This factor represents the value of shipments of liquid crystal displays and other liquid devices (334419E150) as a percent of the value of shipments of Manufacturing of all other specialized electronic hardware [2033925018] in 2004 (U.S. Census Bureau, 2005).
	Chemicals: polyvinyl chloride stabilizer		Plastics material and resin manufacturing [325211]	1.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of thermoplastic resins and plastics materials, polyvinyl chloride [2025350012] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 21.1%, which represents the percent of polyvinyl chloride stabilizers based on tin (Coherent Market Insights, 2025).
	Chemicals: toothpaste		Toilet preparation manufacturing [325620]	0.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of dentifrices, including toothpaste, gels and tooth powders [2010575000] in 2021 by this industry

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					relative to its total output. The result was then multiplied by a factor of 2%, which represents the percent of toothpaste that was based on stannous fluoride (Seraina, 2024).
	Copper alloys		Copper rolling, drawing, extruding and alloying [331420]	1.0	Assessment was based on the production of copper alloys as a percent of all semi-fabricated copper products in the United States (International Copper Study Group, 2023) multiplied by the share that are bronzes (Grand View Research, 2023c) multiplied by the share of bronzes that are phosphor bronzes containing tin (Grand View Research, 2022a).
	Miscellaneous metal forms		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	1.7	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except aluminum) smelting and refining [331410] industry.
	Pipe and tubing		Fabricated pipe and pipe fitting manufacturing [332996]	8.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fabricated iron and steel pipe and all other nonferrous fabricated pipe and pipe fittings [2038275000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 9.3%, which represented the portion of this output that was all other nonferrous fabricated pipe and pipe fittings made from purchased pipe after excluding copper, aluminum, iron, and steel pipes and pipe fittings based on the 2002 Economic Census (U.S. Census Bureau, 2004a).
	Solders		Printed circuit assembly (electronic assembly) manufacturing [334418]	92.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of printed circuit assemblies, loaded boards and modules (printed circuit boards with inserted electronic

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					components) [2041925000] in 2021 by this industry relative to its total output.
	Tinning		Copper rolling, drawing, extruding and alloying [331420]	3.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of copper wire, bare and tinned (nonelectrical) [2032975000] in 2021 by this industry relative to its total output.
	Tinplate		Metal can, box, and other metal container (light gauge) manufacturing [332430]	28.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of steel cans and tinware end products (including ice cream cans, lids, ends, and parts) [2048550000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 90%. Laminated tin-free steel was estimated to penetrate 10% of metal can market (International Tin Association, 2022), suggesting a maximum of 90% of this industry used tinplate.
Titanium ferroalloys	Steel	All domestic ferrotitanium was assumed to be used in steel production	Iron and steel mills and ferroalloy manufacturing [331110]	34.3	Assessment was based on the value of titanium-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of titanium-containing steel produced, the quantity of titanium consumed in various types of steel was divided by estimated elemental contents of tungsten-containing steels (Roskill Information Services Ltd., 2020d) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).
Titanium metal	Aerospace	An estimated 80% of titanium metal's use in the United States was for aerospace applications (U.S. Geological Survey,	Aircraft manufacturing [336411]	93.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft, including all aircraft for U.S. military and any other aircraft built to military specifications [2012100000], Manufacturing of civilian aircraft

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		2019). The remainder was split among the other application categories based on the application fractions reported by Project Blue (2025h) for global demand.			[2012125000], Manufacturing of other aircraft subassemblies and parts for military aircraft (including other aircraft built to military specifications) [2032475000], Manufacturing of other aircraft subassemblies and parts for civilian aircraft [2032500000] in 2017 by this industry relative to its total output.
	Chemical: chlor-alkali	Titanium metal's use in the chemical was assumed to be entirely as anodes for the chlor-alkali industry.	Other basic inorganic chemical manufacturing [325180]	12.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of chlorine, compressed or liquefied [2024625000], Manufacturing of sodium hydroxide (caustic soda) [2024650000] in 2021 by this industry relative to its total output.
	Commercial: bicycles	Titanium metal's use in commercial application was split equally between bicycled and medical applications.	Motorcycle, bicycle, and parts manufacturing [336991]	0.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of bicycles and other cycles, all types, except children's sidewalk bikes [2008700000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 9.5%, which represents the reported percent of bicycles that had titanium frames in 2023 (Grand View Research, 2025a).
	Commercial: medical	Titanium metal's use in the undifferentiated other category was assumed to be equally split between armored vehicles and guided missiles and space vehicles.	Surgical and medical instrument manufacturing [339112]	16.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of orthopedic and prosthetic appliances, other types, excluding intraocular lenses [2010350000], Manufacturing of surgical and orthopedic instruments [2017825000], Manufacturing of surgical and medical internal fixation devices (bone nails, plates, and screws, etc.) [2045800000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 45%, which represents titanium's share of medical alloys (Grand View Research, 2023d).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Desalination and heat-exchangers		Power boiler and heat exchanger manufacturing [332410]	11.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fabricated heat exchangers and steam condensers closed types (excluding nuclear applications) including bar and fin tube [2016375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 21%, which represents titanium's share of the shell and tube heat exchanger global market in 2023 (Grand View Research, 2024c).
	Shipping and marine		Ship building and repairing [336611]	59.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of ships (including combat ships, troop transport vessels, fleet auxiliaries, and service craft), self-propelled, military, new construction [2012275000], Manufacturing of ships, self-propelled, nonmilitary, new construction [2012300000] in 2021 by this industry relative to its total output.
	Power		Electric power generation, transmission, and distribution [221100]	37.2	Assessment was based on the value of shipments of the following NAICS industries: Nuclear electric power generation [221113] and Hydroelectric power generation [221111] in 2017 relative to its total output.
	Transport		Other motor vehicle parts manufacturing [336390]	5.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of exhaust system parts, new (including mufflers, resonators, pipes, and catalytic converters) [2042950000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 25%, which represents the estimated share of exhaust systems that used titanium based on the global titanium motorcycle exhaust pipe market share in 2023 (Verified Market Reports, 2025j).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Other: armored vehicles		Military armored vehicle, tank, and tank component manufacturing [336992]	84.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of tanks [2012325000], Manufacturing of self-propelled weapons and other full tracked combat vehicles and armored utility vehicles [2012350000], Manufacturing of parts for self-propelled weapons, tanks, and other full-tracked combat vehicles and armored utility vehicles [2032815000] in 2021 by this industry relative to its total output.
	Other: Guided missile and space vehicle manufacturing		Guided missile and space vehicle manufacturing [336414]	71.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of complete guided missiles [2012400000] in 2017 by this industry relative to its total output.
Titanium mineral concentrates	Pigments	The proportions of titanium mineral concentrates use in the United States were assumed to be 96% for pigments and 1% for each of the other applications.	Synthetic dye and pigment manufacturing [325130]	42.7	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of titanium dioxide, composite and pure [2024275000] in 2021 by this industry relative to its total output.
	Welding rod coatings		Other general purpose machinery manufacturing [33399A]	1.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of resistance welders, components, accessories, and electrodes [2014800000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 35%, which represents the approximate share of welding electrodes that were based on rutile in 2023 (Market Research Future, 2025).
	Metal		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	12.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of titanium and titanium-base alloy forging and extrusion, ingot and billet, and all other titanium and titanium-base alloy mill shapes (including sheet, plate, tubing, bar, etc.), excluding wire [2027400000] in 2021 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Cemented carbides		Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	6.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of cutting tools (including broaches, reamers, hobs) and all other miscellaneous solid and tipped carbide cutting tools for machine tools and metalworking machinery, excluding tips and blanks [2050000000], Manufacturing of high-speed steel end and solid and tipped carbide end mills, non- and indexable-inserted-blade-type, throwaway-insert-type, and all other miscellaneous milling cutters [2050025000], Manufacturing of carbon and high-speed steel shank and solid and tipped carbide twist drills, including masonry twist drill bits, gun drills, combined drills, countersinks, and counterbores [2050075000], Manufacturing of taps (excluding taps in threading sets and screw plates and inserted chaser types) and precision ground carbide indexable and throwaway inserts for machine tools and metalworking machinery [2050100000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 13.8%. This factor assumes that half of the non-tungsten carbide share of cutting tools are titanium carbides (Market.U.S., 2025a).
	Chemicals		Other basic inorganic chemical manufacturing [325180]	1.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other nonmetallic mineral mining and quarrying [2123A0] industry.
Titanium pigment	Paints and coatings	The proportions of titanium pigment use by application were	Paint and coating manufacturing [325510]	95	An estimated 95% of all paints and coats used titanium dioxide pigments (British Coatings Federation Ltd., 2025; Tronox, 2022).

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	Plastics	estimated based on information provided by the U.S. Geological Survey (2025b) for U.S. shipments of titanium dioxide in 2022.	Other plastics product manufacturing [326190]	28.2	A reported 45% of all plastics pigments were based on inorganic pigments (Global Market Insights, 2024b), of which titanium dioxide pigments represent about 63% (Global Market Insights, 2024a), resulting in an estimated 28% of plastics using titanium dioxide pigments.
	Rubber	The application category of "plastics and rubber" reported by the reference was split between the two applications based on the value of their associated BEA industry's output that are linked to titanium pigment as estimated in this analysis. The proportion of titanium used in paper products was disaggregated from the undifferentiated other applications based on the percent of U.S. shipments of titanium dioxide going to paper in 2019 (Gambogi and Tolcin, 2024). This application fraction was split equally among the	Synthetic rubber and artificial and synthetic fibers and filaments manufacturing [3252A0]	70	Over 68% of industrial rubber products reportedly use titanium dioxide (Huifriend, 2025).
	Paper mills		Paper mills [322120]	44.3	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of bleached bristols and clay-coated, uncoated freesheet, cotton fiber, special industrial, packaging, and industrial converting papers [2023475000], Manufacturing of paper towels, retail packages (rolled, folded, and interfolded) [2008125000], Manufacturing of paper table napkins, industrial and retail packages, bulk and dispenser types [2008475000] in 2021 by this industry relative to its total output.
	Paperboard mills		Paperboard mills [322130]	11.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other solid bleached paperboard, including linerboard, heavyweight cup and round nested food container board, plate, dish, and tray stock, and paperboard for moist, liquid, and oily foods [2023275000] in 2021 by this industry relative to its total output.
	Paper products		Paper bag and coated and treated paper manufacturing [322220]	30.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Synthetic dye and pigment manufacturing [325130] industry.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Other: printer ink	three associated paper-related industries (paper mills, paperboard mills and paper products).	Printing ink manufacturing [325910]	18.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Synthetic dye and pigment manufacturing [325130] industry.
	Other: textiles	The remaining share was split equally among the other applications.	Textile and fabric finishing and fabric coating mills [313300]	18.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Synthetic dye and pigment manufacturing [325130] industry.
	Other: carpets and rugs		Carpet and rug mills [314110]	22.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Synthetic dye and pigment manufacturing [325130] industry.
	Other: cosmetics and toiletries		Toilet preparation manufacturing [325620]	81.9	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Synthetic dye and pigment manufacturing [325130] industry.
	Other: chemical preparations		All other chemical product and preparation manufacturing [3259A0]	10.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Synthetic dye and pigment manufacturing [325130] industry.
Titanium sponge	Titanium metal products	All of titanium sponge consumption was assumed to be for titanium metal products.	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	20.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of titanium and titanium-base alloy forging and extrusion, ingot and billet, and all other titanium and titanium-base alloy mill shapes (including sheet, plate, tubing, bar, etc.), excluding wire [2027400000] in 2019 by this industry relative to its total output.

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Tungsten	Cemented carbides: Cutting tool, machine tool accessories and Industrial molds		Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	33.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of cutting tools (including broaches, reamers, hobs) and all other miscellaneous solid and tipped carbide cutting tools for machine tools and metalworking machinery, excluding tips and blanks [2050000000], Manufacturing of high-speed steel end and solid and tipped carbide end mills, non- and indexable-inserted-blade-type, throwaway-insert-type, and all other miscellaneous milling cutters [2050025000], Manufacturing of carbon and high-speed steel shank and solid and tipped carbide twist drills, including masonry twist drill bits, gun drills, combined drills, countersinks, and counterbores [2050075000], Manufacturing of taps (excluding taps in threading sets and screw plates and inserted chaser types) and precision ground carbide indexable and throwaway inserts for machine tools and metalworking machinery [2050100000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 72.4%, which represents tungsten's share of the cemented carbide market (Market.U.S., 2025a).
	Cemented carbides: special dies and tools		Special tool, die, jig, and fixture manufacturing [333514]	33.4	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of metalworking die and die sets [2016200000], Manufacturing of punches, die parts, and other special tooling [2016225000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 72.4%, which represents tungsten's share of the cemented carbide market (Market.U.S., 2025a).

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	Mill Products: Incandescent lamps, compact fluorescent lamps, and high intensity discharge lamps		Electric lamp bulb and part manufacturing [335110]	16.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of electric lamp bulbs and tubes (including sealed beam lamp bulbs) [2051400000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 20%. This factor represents the approximate percent of U.S. lamp shipments that were halogen-based in 2022 (National Electrical Manufacturers Association, 2023).
	Mill Products: Tungsten inert gas welding		Other general purpose machinery manufacturing [33399A]	0.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of arc welding machines, components, and accessories, excluding electrodes and stud welding equipment [2014775000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 3.%. This factor represents the approximate share of arc welding machines that use tungsten electrodes based on the market size of tungsten welding electrodes as a percent of the entire welding electrode market in 2023 (Allied Market Research, 2024).
	Mill Products: Electrical contact materials		Wiring device manufacturing [335930]	5.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill Products: High temperature applications		Industrial process furnace and oven manufacturing [333994]	10.4	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of parts and attachments for industrial fuel-fired furnaces, ovens, and kilns [2044550000] in 2021 by this industry relative to its total output.

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	Mill Products: X-ray tubes		Irradiation apparatus manufacturing [334517]	41.2	Assessment was based on the revenue generated NAPCS code Manufacturing of irradiation (ionizing radiation) equipment, including X-ray, beta ray, gamma ray, and nuclear [2018025000] less the revenues generated by NAPCS codes Manufacturing of other irradiation equipment [2045212000] and Manufacturing of nuclear medicine equipment [2018025012] in 2017 based on the Economic Census. The result was then multiplied by a factor of 80%, which was the assumed market share for tungsten-based anodes used in X-ray tubes.
	Mill Products: Semiconductors and Integrated Circuits		Semiconductor and related device manufacturing [334413]	2.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Mill Products: Cutting wire		Steel product manufacturing from purchased steel [331200]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Steels		Iron and steel mills and ferroalloy manufacturing [331110]	0.3	Assessment was based on the value of tungsten-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of tungsten-containing steel produced, the quantity of tungsten consumed in various types of steel was divided by estimated elemental contents of tungsten-containing steels (Roskill Information Services Ltd., 2020e) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					values for the different types of steel (Zen Innovations AG, 2025).
	Superalloys: aerospace		Aircraft engine and engine parts manufacturing [336412]	84.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 97%, the percent of superalloys that were estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
	Superalloys: industrial turbines		Turbine and turbine generator set units manufacturing [333611]	52.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 91.1%, the percent of superalloys that were estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
	Other alloys: tungsten heavy metal alloys and wear protection		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	1.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Chemicals: catalysts		Petroleum refineries [324110]	3.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Chemicals: chemical products and laboratory applications		Other basic inorganic chemical manufacturing [325180]	1.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: Vacuum metallizing		Coating, engraving, heat treating and allied activities [332800]	0.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Other: Smart windows		Glass and glass product manufacturing [327200]	0.2	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other: Substitute for lead		Other fabricated metal manufacturing [332999]	7.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Other: Sport and Leisure		Sporting and athletic goods manufacturing [339920]	2.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of golf balls and clubs [2008950000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 19%. This factor represents the share of U.S. golf club from the U.S. golf club

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					and ball market multiplied (Grand View Research, 2022b) by an assumed market share of 30% for tungsten.
	Other: Jewelry		Jewelry and silverware manufacturing [339910]	0.6	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
Vanadium	Steels	<p>The proportions of vanadium's use in the United States by application category were based on data from U.S. Geological Survey (2025b).</p> <p>Vanadium's use in superalloys was split into sub-applications based on data from Eckard (2017).</p>	Iron and steel mills and ferroalloy manufacturing [331110]	5.3	Assessment was based on the value of vanadium-containing steels produced domestically relative to the output of this industry in 2023. To estimate the value of vanadium-containing steel produced, the quantity of vanadium consumed in various types of steel was divided by estimated elemental contents of vanadium-containing steels (Roskill Information Services Ltd., 2021b) and then multiplied by a unit value for each type of steel. The unit values were estimated based on weighted-average import unit values for the different types of steel (Zen Innovations AG, 2025).
	Superalloys: aerospace	<p>Vanadium's use in other alloys were assumed to be mainly titanium-based alloys for aerospace applications.</p> <p>The quantity of vanadium consumed in pigments was estimated based on data from U.S.</p>	Aircraft engine and engine parts manufacturing [336412]	71.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], and Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 82.6%. This factor represented the percent of superalloys

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		Environmental Protection Agency (2022).			that was estimated to be nickel-based (and thus vanadium -containing) for this application in 2016 (Eckard, 2017).
	Superalloys: industrial turbines	Vanadium may have been used in other applications (particularly catalysts), but insufficient data were available to make an assessment.	Turbine and turbine generator set units manufacturing [333611]	39.9	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000], and Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 69.1%. This factor represented the percent of superalloys that was estimated to be nickel-based (and thus vanadium-containing) for this application in 2016 (Eckard, 2017).
	Superalloys: oil and gas		Mining and oil and gas field machinery manufacturing [333130]	36.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of rotary oil and gas field drilling machinery and equipment, excluding parts [2013050000], Manufacturing of other oil and gas field drilling machinery and equipment, excluding parts [2013075000], Manufacturing of oil and gas field production machinery and equipment (excluding pumps and parts) [2013100000], and Manufacturing of oil and gas field derricks, substructures and accessories, including well-surveying machinery and equipment and well-logging equipment [2013150000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 82.1%. This factor represented the percent of superalloys that was estimated to be nickel-based (and thus vanadium -containing) for this application in 2016 (Eckard, 2017).

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Superalloys: automotive		Other motor vehicle parts manufacturing [336390]	3.3	Assessment was based on the value of the North American turbocharger market (Global Market Insights, 2025a) multiplied by 51% to approximate the share of superalloys that were nickel-based (Eckard, 2017) divided by the total industry output in 2023.
	Other alloys		Aircraft manufacturing [336411]	84.0	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft, including all aircraft for U.S. military and any other aircraft built to military specifications [2012100000], Manufacturing of civilian aircraft [2012125000], Manufacturing of other aircraft subassemblies and parts for civilian aircraft [2032500000], Manufacturing of other aircraft subassemblies and parts for military aircraft (including other aircraft built to military specifications) [2032475000] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 90%, which was the estimated percent of titanium alloys that contained vanadium (Roskill Information Services Ltd., 2021b).
	Pigments		Synthetic dye and pigment manufacturing [325130]	1.5	Assessment was based on the global market value for bismuth vanadate pigments, which was estimated at \$350 million in 2024 (Verified Market Reports, 2025c). Assuming the usage was proportional to U.S. share of world GDP, the U.S. share of that market value was divided by industry output total in 2023.
Zinc, mined	Zinc processing	All U.S. consumption of zinc concentrates was assumed to be processed in zinc smelters.	Nonferrous metal (except aluminum) smelting and refining [331410]	3.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of refined primary unalloyed zinc slab and zinc-base alloy, including unalloyed dust [2027431000] in 2021 by this industry relative to its total output.

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
Zinc, smelted	Galvanizing steel	The proportions of zinc's use by different industries in the United States was estimated based on information from the U.S. Census Bureau's Economic Census for the material use of zinc and zinc-base alloy shapes and forms under Material Code 33149105 and zinc oxide under Material Code 32521202 (U.S. Census Bureau, 2012a) and supplemented with information from Chemical Data Reporting database (U.S. Environmental Protection Agency, 2022) for zinc and zinc oxide.	Iron and steel mills and ferroalloy manufacturing [331110]	17.2	Assessment was based on the percent of net shipments of steel mill products that were galvanized steel in the United States in 2023 (American Iron and Steel Institute, 2023a).
	Galvanizing steel product manufacturing from purchased steel		Steel product manufacturing from purchased steel [331200]	17.2	Assessment was based on the percent of net shipments of steel mill products that were galvanized steel in the United States in 2023 (American Iron and Steel Institute, 2023a).
	Copper alloys		Copper rolling, drawing, extruding and alloying [331420]	10.1	Assessment was based on the quantity of copper alloys produced as a percent of all U.S. semi-fabricated copper and copper alloy production in 2022 (International Copper Study Group, 2023) multiplied by the percent of copper alloys that were brasses globally (Grand View Research, 2023c).
	Rolled and alloyed zinc		Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490]	3.2	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of refined secondary alloyed and unalloyed zinc, including all ASTM-specification zinc [2027427000] in 2021 by this industry relative to its total output.
	Foundries		Nonferrous metal foundries [331520]	8.4	Assessment was based on the value of zinc and zinc-base alloy castings shipments relative to the total value of nonferrous castings in 2003 (U.S. Census Bureau, 2004b).
	Hardware		Hardware manufacturing [332500]	24.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying [331490] industry.
	Batteries, primary		Primary battery manufacturing [335912]	62.8	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of primary batteries, excluding lead acid [2010950000] in 2018 by this industry relative to its total output. The result

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					was then multiplied by a factor of 67%, which represented the approximate percent of global primary battery that used zinc (alkaline, zinc-carbon, and silver-oxide) (Market.U.S., 2025b) in 2024.
	Paint and pigments		Synthetic dye and pigment manufacturing [325130]	1.0	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other white opaque pigments [2024300000] in 2017 by this industry relative to its total output. The result was then multiplied by a factor of 40%, which was the approximate percent of white opaque pigments that were based on zinc oxide in 1997 (U.S. Census Bureau, 2004a).
	Fertilizers		Fertilizer manufacturing [325310]	4.8	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Tires		Tire manufacturing [326210]	5.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other rubber products		Other rubber product manufacturing [326290]	8.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Pharmaceuticals		Pharmaceutical preparation manufacturing [325412]	5.1	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of pharmaceutical preparations, acting on skin, for human use [2010275000], Manufacturing of other cough and cold preparations, including topical preparations, cough drops, and others, non-

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					prescription [2010225031], Manufacturing of cough and cold preparations, decongestants, including nasal sprays and nose drops, non-prescription [2010225018] in 2017 by this industry relative to its total output.
	Printing ink		Printing ink manufacturing [325910]	0.3	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Paper bleaching		Paper mills [322120]	3.0	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Soaps		Soap and cleaning compound manufacturing [325610]	0.1	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
Zirconium	Aerospace turbine blades	<p>The proportions of zirconium's use by application for the United States were obtained from Mordor Intelligence (2024c).</p> <p>Zirconium's use in foundries was split among the sub-applications based on data from the 2012</p>	Aircraft engine and engine parts manufacturing [336412]	84.2	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of military aircraft engines (including other aircraft engines built to military specifications) [2029400000], Manufacturing of civilian aircraft engines [2029425000], Manufacturing of parts and accessories for military aircraft engines [2029450000], Manufacturing of parts and accessories for civilian aircraft engines [2029475000] in 2018 by this industry relative to its total output. The result was then multiplied by a factor of 97%, the percent of superalloys that were estimated to be

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
		Economic Census (U.S. Census Bureau, 2012a).			cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
	Chemical processing	Zirconium's use in chemicals was initially split among several applications based on data from the Zircon Industry Association (2019). Within the gemstone and technical ceramics category under chemicals, the uses were split equally among gemstones, technical ceramics and coatings for turbine blades. Within the technical ceramics, the use was split equally among the three industries. Within the coatings for turbine blades, 80% was allocated to aerospace and 20% was allocated for gas turbines. Within the chemicals category, the paints and driers sub-applications were combined. Within the chemicals category, the use in	Power boiler and heat exchanger manufacturing [332410]	4.9	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fabricated heat exchangers and steam condensers closed types (excluding nuclear applications) including bar and fin tube [2016375000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 9.1%, which represents the estimated market share of zirconium in the shell and tube heat exchanger U.S. market (Grand View Research, 2024c) based on the share of the "other" materials and the fraction of all applications most likely to contain zirconium (chemical, petrochemical, power generation).
	Chemicals: coatings		Paint and coating manufacturing [325510]	3.5	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Chemicals: deodorants		Toilet preparation manufacturing [325620]	7.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of cosmetics and other toilet preparations [2010675000] in 2021 by this industry relative to its total output. The result was then multiplied by a factor of 22.6%, which represents the share of this NAPCS under the following products from the 2002 Economic Census (U.S. Census Bureau, 2004a): Underarm deodorants, roll-on, solid, and other types [325620G231], Underarm deodorants, aerosol and spray type [325620G221], multiplied by 93% share for aluminum-based deodorants (Research and Markets, 2024a; Research and Markets, 2024b)

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
	Chemicals: gemstones	nuclear applications was assumed to be for metals overall. That sub-application was split further into multiple metal proportional to the uses as reported by Mordor Intelligence (2024c).	Miscellaneous nonmetallic mineral products [327999]	7.8	Assessment was based on the value of the North American share of the global cubic zirconia market (Verified Market Reports, 2025a) multiplied by an assumed 50% share for the United States as percent of this industry's total output in 2023.
	Chemicals: paper coatings		Paper mills [322120]	0.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of other coated and processed papers, excluding for packaging uses [2023500000] in 2021 by this industry relative to its total output.
	Chemicals: technical ceramics, cutting		Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing [33351B]	29.5	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of cutting tools (including broaches, reamers, hobs) and all other miscellaneous solid and tipped carbide cutting tools for machine tools and metalworking machinery, excluding tips and blanks [2050000000] in 2021 by this industry relative to its total output.
	Chemicals: technical ceramics, grinding		Abrasive product manufacturing [327910]	34.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of nonmetallic coated abrasive products and buffing wheels, polishing wheels, and laps [2051375000] in 2021 by this industry relative to its total output.
	Chemicals: technical ceramics, high-stress parts		Valve and fittings other than plumbing [33291A]	4.3	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of industrial ball valves (all metals, pressures, and types), including manual and power-operated, on-off valves, excluding parts [2044875000] in 2021 by this industry relative to its total output.
	Gas turbines		Turbine and turbine generator set units manufacturing [333611]	52.6	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of turbine generator sets, excluding prime mover generator sets [2015700000], Manufacturing of steam turbines and other vapor turbines [2015725000],

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					Manufacturing of gas turbines, excluding aircraft (all sizes) [2015775000] in 2020 by this industry relative to its total output. The result was then multiplied by a factor of 91%, the percent of superalloys that was estimated to be cobalt- and nickel-based for this application in 2016 (Eckard, 2017).
	Nuclear		Electric power generation, transmission, and distribution [221100]	32.2	Assessment was based on the value of nuclear electricity generation [221113] relative to the value of all electricity generation in 2017
	Other chemicals		Other basic inorganic chemical manufacturing [325180]	0.01	Assessment was based on the estimated expenditures of this industry on this mineral commodity relative to this industry's expenditures on all goods and services from the Other basic inorganic chemical manufacturing [325180] industry.
	Other metals: automotive parts		Other motor vehicle parts manufacturing [336390]	4.6	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of motor vehicle frames, new [2031800000] in 2021 by this industry relative to its total output.
	Refractories		Industrial process furnace and oven manufacturing [333994]	36.1	Assessment was based on the value of shipments of the following NAPCS code: Manufacturing of fuel-fired industrial process furnaces, ovens, and kilns, excluding parts and attachments [2017250000], Manufacturing of electric (excluding high-frequency induction and dielectric and resistance-heated) metal processing and heat-treating furnaces, excluding parts and attachments [2017350000] in 2021 by this industry relative to its total output.
	Zircon flour and milled sand: aluminum foundries		Nonferrous metal foundries [331520]	14.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of aluminum and aluminum-base alloy sand castings (excluding cast aluminum cooking utensils) [2028125000], Manufacturing of aluminum and

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					aluminum-base alloy investment castings (excluding cast aluminum cooking utensils) [2028175000], Manufacturing of aluminum and aluminum-base alloy permanent and semipermanent mold castings (excluding cast aluminum cooking utensils) [2028150000], Manufacturing of other aluminum and aluminum-base alloy castings, excluding die-castings (excluding cast aluminum cooking utensils) [2028200000] in 2021 by this industry relative to its total output.
	Zircon flour and milled sand: ferrous metal foundries		Ferrous metal foundries [331510]	7.7	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of steel investment castings, including carbon, alloy and stainless steel, hi-temp metal (iron, nickel or cobalt-based alloys) [2028025000], Manufacturing of high alloy steel castings, excluding investment [2028075000], Manufacturing of other ductile iron castings for automotive uses [2027825000], Manufacturing of all other ductile iron castings for all other uses, including valve, construction and utility, machinery, electric and electronic equipment, heat-resistant parts (including coke oven doors) [2027850000] in 2021 by this industry relative to its total output. The result was then multiplied by an assumed market share of zirconium of 50%.
	Zircon flour and milled sand: nonferrous metal foundries		Nonferrous metal foundries [331520]	10.5	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of other nonferrous foundries castings (excluding die-casting and aluminum) including nickel and nickel-base alloy, zinc and zinc-base alloy, magnesium and magnesium-base alloy, and all other nonferrous castings [2028300000], Manufacturing of copper and copper-base alloy foundries (excluding die-casting)

Mineral commodity	Application category	Data sources and notes regarding applications	Associated BEA industry [code]	Estimated percent of BEA industry's output that used this mineral commodity	Basis for assessment for percent of BEA industry's output that used this mineral commodity
					including sand, leaded red, manganese, aluminum bronzes, and all other copper castings (mold, centrifugal, investment, etc.) [2028275000] in 2021 by this industry relative to its total output. The result was then multiplied by an assumed market share of zirconium of 50%.
	Zircon opacifier (ceramics)		Clay product and refractory manufacturing [327100]	47.8	Assessment was based on the value of shipments of the following NAPCS codes: Manufacturing of vitreous plumbing fixtures, vitreous china lavatories, and flush tanks, including all other plumbing accessories and earthenware [2038400000], Manufacturing of vitreous china, porcelain, and earthenware (semivitreous) table and kitchenware (including household, hotel, or commercial uses) (including bone and feldspar) [2007400000], Manufacturing of clay floor and wall tile, glazed and unglazed (including ceramic mosaic tile) [2036000000], Manufacturing of clay refractories [2041450000] in 2021 by this industry relative to its total output.

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Appendix 5. Python implementation of economic impacts model

This appendix documents the complete Python-based implementation developed to estimate the economic effects of mineral supply disruption trade scenarios. As noted in the report, the model used input–output data from the U.S. Bureau of Economic Analysis (BEA) and centered around a structured convex optimization routine implemented using the CVXPY library. This implementation supports the analysis of mineral supply disruption scenarios, enabling a systematic evaluation of the macroeconomic and industry-level impacts resulting from changes in the availability and pricing of these minerals.

Input data structure and computational workflow

The model required the following data inputs, provided in Microsoft Excel® format with multiple sheets:

- **Direct Requirements matrix:** Matrix/inter-industry coefficients (direct requirements matrix) from BEA data representing intermediate inputs per dollar of output.
- **Original industry data:** Industry-level input-output accounts derived from BEA tables with the following information:
 - BEA's industry code
 - Industry output
 - Value added
 - Final demand
 - Intermediate demand
- **Mineral commodity to industry mapping:** A dataset linking mineral commodity consumption to their downstream consuming industries. This includes information regarding the quantity of each mineral commodity used by industry and the percent of each industry's output that uses the mineral commodity (details are provided in appendix 4).
- **Scenarios:** Each row specifies a unique scenario with the following parameters:
 - Postdisruption to predisruption price ratio for affected mineral commodities (P'/P)
 - Net disruption level (n' , percentage reduction in mineral commodity available)
 - Mineral production growth rate outside the restricted country
 - Identity of the restricting country
- **Industry capacity utilization:** Ratios representing the baseline utilization of production capacity for each industry.

The code first validates and ingests the data, standardizing formats and filling missing values where applicable. A key preprocessing step involves constructing an *expanded industry dataset* by identifying industries that rely on the mineral specified in each scenario. Each industry's exposure was weighted by the share of its output dependent on that mineral, allowing for customized disruption modeling. This expanded data forms the input for the optimization problem.

The core model was formulated as a constrained quadratic program. The decision variable corresponded to postdisruption output of each industry, and the objective function penalized squared deviations from baseline value added, final demand, and intermediate demand, thereby favoring minimal adjustment while enforcing supply-side and demand-side constraints. These constraints were derived from the input–output linkages, price shocks, and domestic production limits.

Optimization and solver configuration

We solved the optimization problem using the Clarabel solver through the CVXPY modeling framework. Clarabel is a conic interior-point solver, developed by Goulart and Chen (2024), optimized for large-scale convex programs expressed over standard cones, including the nonnegative orthant and second-order cones. In this application, Clarabel handles quadratic objectives and equality constraints that reflect real-world capacity and demand restrictions.

We implemented the optimization using CVXPY version 1.6.5, (CVXPY, 2025) where constraints are expressed symbolically and passed to the solver without explicit transformation into standard conic form. The solver was chosen for its performance in medium- to large-scale structured problems and for its compatibility with Python-based workflows, allowing for scenario-based batch simulations.

Each scenario was solved independently, which enables parallelization. The input-output problems involve over 400 industries and nearly one thousand constraints, making solver efficiency a key concern. Clarabel's ability to maintain numerical robustness and relatively fast convergence makes it ideal for this use case. Although Clarabel was the default solver, the implementation can seamlessly be extended to support other solvers such as MOSEK, OSQP, or SCS.

Software environment and package dependencies

We conducted all computations in Python version 3.11.8 (Python Software Foundation, 2024). The following packages are essential to run the model:

- **NumPy 1.25.2:** For linear algebra and numerical computation
- **Pandas 2.0.2:** For structured data manipulation and reshaping
- **CVXPY 1.6.5:** For modeling and solving convex optimization problems
- **Clarabel 0.9.0:** Default conic solver for CVXPY in this version
- **Pyxlsb 1.0.10:** For reading binary Excel files where applicable
- **Concurrent.futures:** For managing parallel execution of scenarios

We ran the model on a workstation equipped with an Intel vPRO Core i9 processor and 64 GB of physical RAM. Runtime for 1,205 scenarios averaged approximately 30-35 minutes when processed in parallel.

Parallel processing

Given the scenario-based nature of the analysis, we implemented parallel processing to reduce total runtime. The `concurrent.futures.ProcessPoolExecutor`¹ interface was used to distribute individual scenario runs across multiple Central Processing Unit (CPU) cores. Each scenario was treated as an independent task, allowing near-linear speed-up with the number of available cores. Failures in individual scenarios (for example, due to infeasibility or numerical issues) were logged without halting the full batch run, ensuring robustness of the pipeline.

¹ `concurrent.futures` is a standard Python module that enables parallel execution of tasks using threads or processes, providing an interface for managing asynchronous computations. For more details, visit <https://docs.python.org/3/library/concurrent.futures.html>.

Output Format

Upon completion, the model generated the following structured outputs:

- **Scenario-level macroeconomic summary:**
 - Change in Gross Domestic Product (GDP) due to higher input prices paid by consuming industries
 - Change in GDP due to output contraction in consuming industries
 - Change in GDP due to increased revenues for producing industries
 - Change in GDP due to output expansion in producing industries
- **Industry-level impact by scenario:**
 - New industry output levels
 - Changes in value added by industry, with and without price effects
- **Run log and diagnostics:**
 - Scenario IDs with failed optimization runs
 - Type of failure (for example, primal infeasibility, numerical error)
 - Solver status and convergence information

Outputs were saved in Microsoft Excel® format with separate sheets for summary metrics, industry-level results, and diagnostics. This structure facilitated downstream visualization, statistical analysis, and reporting.

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Appendix 6. Natural breaks classification

Overview

To classify¹ the probability-weighted net decrease in U.S. gross domestic product (GDP) into interpretable and statistically meaningful categories, we used the Jenks natural breaks optimization method (Jenks, 1967). This technique is specifically designed to identify partitions that minimize intra-class variance and maximize inter-class variance. The method is particularly efficient in revealing natural groupings within skewed or heterogeneously distributed datasets, making it suitable for applications where data-driven classification is required.

Data preparation and transformation

The classifying procedure was applied to a filtered and transformed version of the dataset to ensure the stability and interpretability of the resulting classes. First, only non-negative values were retained for the analysis. This restriction ensured that subsequent logarithmic transformations were well-defined and avoided distortion from undefined negative inputs. Second, a base-10 logarithmic transformation was applied to the data prior to classification. This transformation is commonly used to compress skewed distributions, highlight relative differences across orders of magnitude, and improve the detection of latent classes in data exhibiting multiplicative effects.

Determining the optimal number of breaks

The Jenks natural breaks optimization method requires specifying the number of classes in advance. To select this number in a data-driven manner, we used a two-step evaluation process:

- **Goodness of Variance Fit (GVF):** For each candidate number of classes k from 1 to 10, the algorithm computes the GVF score, defined as:

$$GVF = \frac{\text{Total Variance} - \text{Within-Class Variance}}{\text{Total Variance}} \quad \text{A6.1}$$

Values closer to 1 indicate a more optimal classification, as they reflect low within-class variance relative to the overall variability in the data. The GVF score increases with the number of classes and converges to 1 when the number of classes equal the number of data points, indicating overfitting. To avoid this and determine the optimal number of classes, we implemented the Elbow method.

- **Elbow Method for GVF Curve:** To identify the point at which increasing the number of breaks yields diminishing improvements, we plotted the GVF scores against the number of classes. The "elbow" in this curve was used as the heuristic cutoff. The inflection point on the GVF curve was located by the method suggested by Satopaa and others (2011), indicating that additional breaks beyond this threshold offered minimal marginal improvement in the classification quality.

¹ While we refer to Jenks natural breaks optimization method as a classification method throughout this study, it is technically a data clustering algorithm. We use the term "classification" interchangeably for clarity and consistency with common usage in data visualization and cartography.

This selection process provides both a quantitative and visual criterion for determining the most appropriate number of natural classes.

The Jenks natural breaks optimization method iteratively adjusts class boundaries to optimize the tradeoff between within-class and between-class variance. Specifically:

- For each value of k , candidate class boundaries are initialized and adjusted using an iterative algorithm to minimize the sum of squared deviations within each class.
- At convergence, the GVF score is computed to assess the classification quality for that k .
- The process is repeated for a range of candidate class counts, and the configuration with the best tradeoff (as determined by the elbow in the GVF curve) is selected as the final model.

The combination of GVF score with Elbow method ensures that the resulting classification reflects the intrinsic structure of the dataset, rather than being imposed by arbitrary or evenly spaced thresholds.

Implementation

- We conducted the analysis on log-transformed, non-negative data to stabilize variance and normalize scale.
- We used a knee-point detection algorithm to automate identification of the GVF elbow, which occurred at $k = 5$.

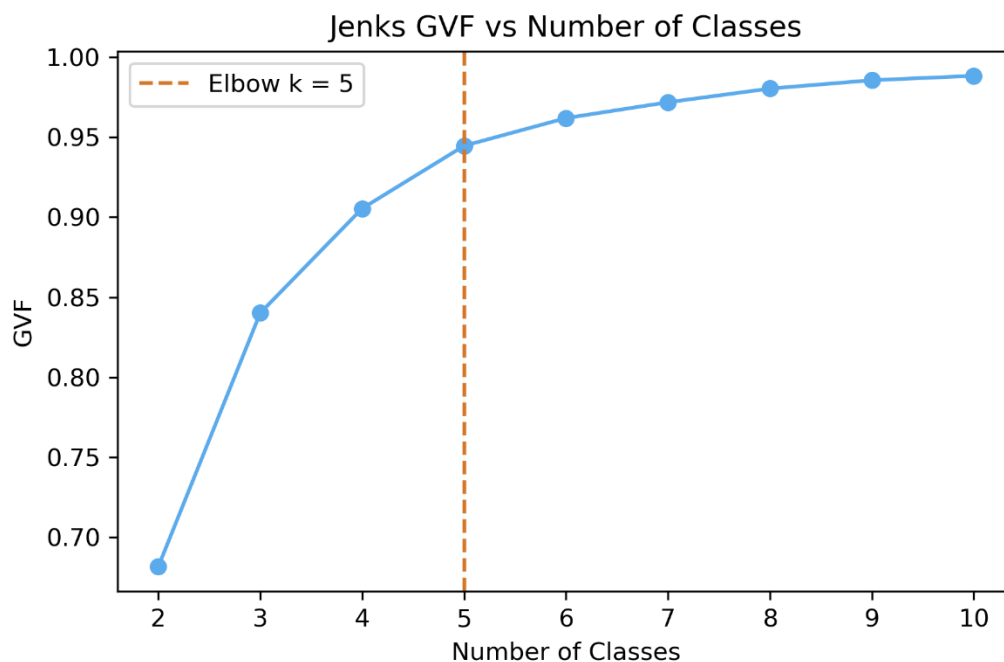


Figure A6.1: Goodness of variance fit (GVF) vs. Number of Classes, with the optimal number of classes identified at the elbow point ($k=5$).

- The Jenks natural breaks optimization method was applied to the optimal number of classes, which was $k = 5$ in this case.

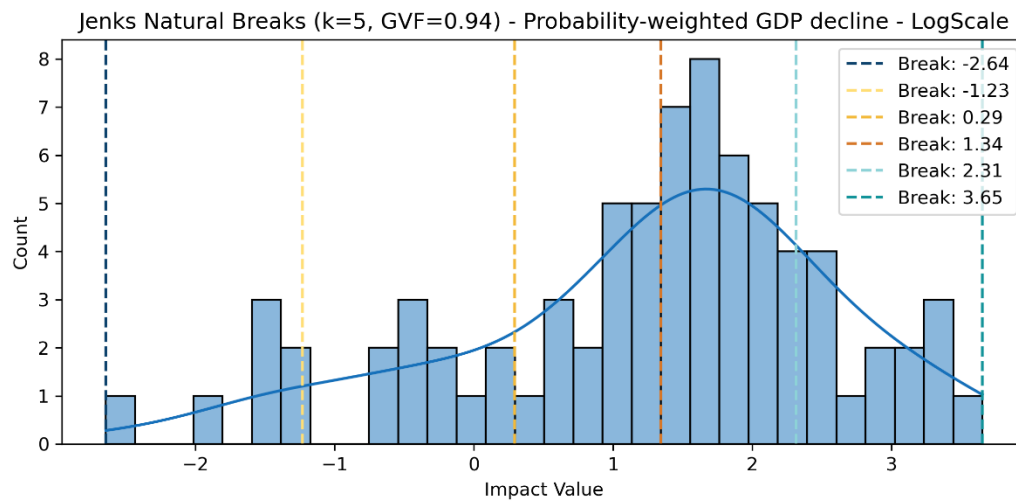


Figure A6.2: Jenks natural breaks optimization method applied to log-transformed expected gross domestic product (GDP) decline values. Histogram bars represent the distribution of observed impact values, overlaid with a kernel density estimate (blue line). Vertical lines indicate the optimized breakpoints. GVF=goodness of variance fit

- The resulting class boundaries were transformed back for interpretability in the original scale, with cut-off intervals at 0.00 to 0.06, 0.06 to 1.97, 1.97 to 21.97, 21.97 to 205.76, and 205.76 to 4,497.89.

All computations were performed using reproducible Python code, with graphical output illustrating both the GVF curve and final classification breaks.

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