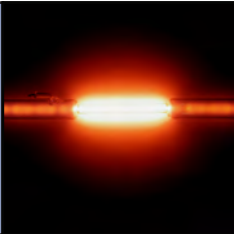


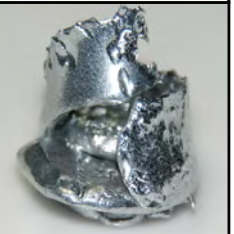






World Minerals Outlook—Cobalt, Gallium, Helium, Lithium, Magnesium, Palladium, Platinum, and Titanium Through 2029

					Helium He^2 4.0026
	Lithium Li^3 6.938				
	Magnesium Mg^{12} 24.305	Titanium Ti^{22} 47.88		Cobalt Co^{27} 38.933	Gallium Ga^{31} 63.723
			Palladium Pd^{46} 106.42		
			Platinum Pt^{78} 195.08		

Scientific Investigations Report 2025–5021

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By Elisa Alonso, Amanda S. Brioche, Ruth F. Schulte, Loyd M. Trimmer, Ji-Eun Kim, Andrew L. Gulley, and David G. Pineault

Scientific Investigations Report 2025–5021

U.S. Department of the Interior
U.S. Geological Survey

U.S. Geological Survey, Reston, Virginia: 2025

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Preface

Every segment of the economy depends on materials that comprise or derive from nonfuel mineral commodities, whether directly or indirectly. This reliance is not new because human societies have used nonfuel mineral commodities—including copper, iron, gold, lead, mercury, silver, and tin—since antiquity to forge tools, build civilizations, and explore the world. However, the number of mineral commodities currently used and the rate at which they are extracted, processed, and consumed are unprecedented. Our ever-expanding understanding of the uses of mineral commodities and the elements contained within these commodities has enabled advances in science and technology, rapid economic growth, and rising living standards.

As demand continues to grow and evolve, evaluating the current and potential future supplies of mineral commodities can help to inform whether they will be sufficient to meet demand growth and also help to inform the potential for supply disruption. It is notable that the extraction and production of many commodities, especially nonferrous minor and precious metals, is concentrated in a few countries. Countries currently supplying mineral commodities have the advantage of in-place infrastructure, skilled labor, and known mineral endowments that provide them with better investment opportunities for new and expanded production. Countries with low domestic mineral endowments must either invest abroad or import to meet their mineral requirements. This dependency exposes the downstream industries that rely on mineral commodities to numerous risk factors, including geopolitical tension, currency manipulation and volatility, property rights disputes, natural disasters, trade restrictions, energy price volatility, and resource nationalism.

The goal of this publication is to provide recent mine production and future capacity outlooks for an initial group of nonfuel mineral commodities. This first “World Minerals Outlook” includes information for cobalt, gallium, helium, lithium, magnesium, palladium, platinum, and titanium. For each of these commodities, a possible future supply scenario is presented based on reported data of planned and announced mine production capacity at the time of this report. Moreover, the scope of this world outlook is limited to the 2025–2029 timeframe—the time horizon that affords an assessment of greenfield or brownfield projects and the expansion (or closure) of existing mines that might occur with a reasonable degree of certainty.

Specifically, the capacity projections for this 5-year time horizon include:

- currently operating facilities;
- planned expansion projects that have met the typical milestones associated with a mining or processing investment, such as proven or probable reserves, a completed feasibility study, established financing, approved permitting, and project timelines; and
- the capacity of those facilities that have announced short-term reductions in production or temporary care-and-maintenance status (typically owing to oversupply and low prices in the commodity market) but can be brought online rather quickly. Any mines or processing operations that had indications of future closures, even if those mines were operational in 2024, were excluded from capacity projections in this report.

Readers may recognize the similarity of this work to the USGS “Regional Summaries” presented in Volume III: Area Reports: International of the USGS Minerals Yearbook series before 2016. This “World Minerals Outlook” series is an outgrowth and expansion of the “Regional Summaries” that combines historical production and capacity data and an outlook for future supply capacity. This publication also complements other USGS publications, including the annual Mineral Commodity Summaries and other Minerals Yearbook series.

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Supplemental Information

Mineral resources refers to the physical aggregate of mineral deposits in a region above some lower cutoff.

A bankable or definitive feasibility study is a detailed analysis of all relevant project components that demonstrates the economic feasibility of a project with sufficient certainty to allow a decision to finance and develop a mine.

Abbreviations

BIL	Bipartisan Infrastructure Law
COVID–19	novel coronavirus 2019
DPA	Defense Production Act of 1950
EV	electric vehicle
GDP	gross domestic product
IEA	International Energy Agency
IRA	Inflation Reduction Act
LED	light-emitting diode
LME	London Metal Exchange
MRI	magnetic resonance imaging
NAICS	North American Industry Classification System
PGM	platinum-group metal
USGS	U.S. Geological Survey

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By Elisa Alonso, Amanda S. Brioché, Ruth F. Schulte, Loyd M. Trimmer, Ji-Eun Kim, Andrew L. Gulley, and David G. Pineault

Abstract

Given the rapid expansion in the demand for mineral commodities that underpin worldwide economic growth and technological advancement, information regarding expected country-level mine production and production capacity is becoming increasingly important to industry stakeholders, end users, and policymakers. Production capacity can limit future supply, depending on how rapidly that capacity is able to expand. Current capacity can be evaluated on the basis of past production. Decreases to future capacity can be taken into account from announcements of planned shutdowns of mines or processing facilities, which are frequently publicized well in advance of such closures. Likewise, capacity expansions, which usually involve multiple stages—such as permitting, financing, and construction (all of which take time)—can also be estimated. As such, it is possible to evaluate midterm future capacity based on estimates of today's capacities along with consideration of future investment plans. This World Minerals Outlook provides estimated capacities for cobalt, gallium, helium, lithium, magnesium, palladium, platinum, and titanium for 2025 through 2029.

The results of this analysis indicate that two mineral commodities important to the manufacture of lithium-ion batteries—cobalt and lithium—are expected to have large capacity growth in the next few years, likely owing to expectations for increased demand for these batteries. For gallium, helium, palladium, and platinum, capacity is expected to remain stable or exhibit moderate growth. Still, these expected capacity levels are higher than current production, allowing for future production growth. The production capacity outlook is opaque for magnesium and titanium metal, which have a significant fraction of current production in nonmarket economies, such as China and Russia. Ultimately, though, where free market conditions prevail, full utilization of capacity potential for those commodities is likely to depend on supply deficits and prices that are above production costs.

Introduction

The markets for mineral commodities exhibit fluctuations that largely follow the overall business cycle. However, mineral commodity markets are also influenced by factors such as government intervention, high concentration of production, production costs, exchange rates, and trade policy. Some nonfuel mineral commodities, such as aluminum, copper, iron ore, steel, and tin, feature a homogenous supply, many producers, and numerous buyers. Other mineral commodities, such as cobalt, gallium, germanium, lithium, and rare earths, have end uses with highly customized specifications and much smaller markets. For example, the global market for steel in 2024 was approximately 1.9 billion metric tons, whereas the market for mined cobalt was only about 240,000 metric tons in that year (U.S. Geological Survey, 2025). Still other mineral commodities, such as gold, platinum-group metals, and silver, are used as investments, which can create disruptions that are unrelated to underlying market fundamentals.

Generally, prices rise as demand exceeds supply. The market restores equilibrium when supply has increased, demand has decreased, or when there is a combination of these two factors. If additional existing capacity is available, supply can respond quickly to rising demand, but if mines or processing plants are operating at or close to full capacity, new capacity will be required, which takes time and capital. Changes in demand and supply can transpire gradually or can happen suddenly. Abrupt changes in demand or supply can usually be tied to some event, whether manmade or natural. For example, a government policy that encourages the use of electric vehicles (EVs) can create a sudden surge in demand for the materials needed to manufacture them. On the supply side, production could be disrupted owing to natural disasters, labor strikes, higher energy costs, government quotas and regulations, or trade policy. Most changes, however, happen gradually over time. Global demand for most mineral commodities has been increasing over the past few decades owing to population and economic growth. Supply has grown for most commodities, too, with new (greenfield)

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Summaries are provided in the following pages for each nonfuel mineral commodity covered in this report. Specifically, the summaries review each commodity's historical production and the outlook for future production capacity. This outlook estimates capacity for projects where the mineral is a main product, coproduct, or byproduct.

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Production and Capacity Utilization

Production capacity provides an estimate of the maximum production quantity that can be expected in the future based on known projects that could be online in any given year. Production capacity expansion can be evaluated from announced projects, whereas capacity shutdowns can be tracked by identifying aging plants, depleted resources, and announced life of mine and mine closure plans. Given typical timelines for building new mines and the 5-year timeframe of this study, planned construction were deemed to be a good estimate of future capacity. Meanwhile, mine capacity that has been idled owing to temporary price declines can still be brought back online in the future if the site is put on care-and-maintenance status. For this study, capacity that is on care-and-maintenance status is considered available.

Production is more closely tied to price and more subject to disruptions than capacity, making future production outlooks much more challenging to assess than future capacity. For example, there can be production disruptions from events such as labor strikes, natural disasters, political upheaval, and power outages. Forecasting price volatility and quantifying potential production disruptions using price elasticity of supply are outside the scope of this publication.

Based on historical data of U.S. capacity utilization, the expectation is that, across a given industry, production is a percentage of total capacity that varies over time and usually in accordance with price fluctuations throughout the business cycle. Although any single facility is capable of operating above capacity temporarily, doing so for an extended amount of time increases the risk of worker safety, damage to equipment and potential violations of emissions permits. On the other hand, a low operating rate is usually a sign of poor economic performance and is inefficient in profit-driven companies. The U.S. Federal Reserve publishes historical data of capacity utilization collected by the Federal Reserve Board (Board of Governors of the Federal Reserve System, 2024a) for industries related to mineral commodities and to manufacturing, including mining, primary and fabricated metals, nonmetallic mineral products, and chemicals. The USGS provides production data to the Federal Reserve Board monthly on 16 mineral commodities and provides capacity

utilization rates twice a year to support the analysis. Summary data are also published for the manufacturing industry as a whole.

Domestic capacity utilization in these mineral commodity-adjacent industries (fig. 1) has generally fluctuated between 65 and 90 percent during the past 20 or more years. Notable exceptions include the nonmetallic mineral product sector (North American Industry Classification System [NAICS] industry code 327) and the primary metal sector (NAICS 331), which saw capacity utilization plunge to 45 percent and 50 percent, respectively, during the 2007–9 recession. Because these sectors are used in building and construction, it stands to reason that their utilization rates would struggle during an economic downturn (Bureau of Economic Analysis, 2024). An anomaly was observed again starting in 2020 when capacity utilization plummeted to about 50 percent for the primary metal sector and 60 percent on average for other sectors, which is when the 2019 novel coronavirus (COVID–19) spread to the United States (Board of Governors of the Federal Reserve System, 2024b).

Figure 1 shows data for the United States only; capacity utilization rates can differ significantly across countries and are usually a function of the performance of individual mining operations on the industry cost curve. Low-cost operations tend to operate at higher capacity utilization than higher cost operations until demand reaches a level where more supply is needed in the market and the prices the market is willing to pay can justify production from the higher cost capacity. However, some countries use subsidies, tax breaks, and other incentives; this creates overcapacity and tends to keep prices and operating rates of competitors in other countries low. One example of this is China where state support for favored industry sectors has led to persistent overinvestment

(Shambaugh, 2024). China’s support of its industrial sector dwarfs that sector’s competitors in relative and absolute terms. For example, in 2019 China spent 1.73 percent of its gross domestic product (GDP) on various incentive programs for mining and mineral commodity production (DiPippo, Mazzocco, and Scott, 2022). South Korea was second in mineral industry investment, spending 0.67 percent as a share of GDP, whereas the United States came in seventh at 0.39 percent of GDP (DiPippo, Mazzocco, and Scott, 2022).

Investments in China have generated massive overcapacity in several critical sectors (Shambaugh, 2024). For example, as of 2023, total production of lithium-ion batteries in China totaled over 2 terawatt hours (Shambaugh, 2024), with global demand being roughly half that amount. China’s solar panel production is also roughly twice the size of global demand. In the EV market, China’s production of cars currently equals global demand but is expected to surpass global demand by 2025 (Shambaugh, 2024, citing BloombergNEF and the International Energy Agency [IEA]). Overcapacity puts downward pressure on prices and profitability for other global producers that do not benefit from government support.

China’s low operating rates increase the possibility that operations outside of China may never come to fruition because Chinese facilities can quickly increase production and keep downward pressure on prices (Boullenois, Kratz, and Rosen, 2024; Wu, Karmer, and Weidensteiner, 2024). Such different approaches to investment and capacity growth across countries add to the uncertainty in this outlook analysis. Capacity data thus provide only a rough approximation for future supply scenarios.

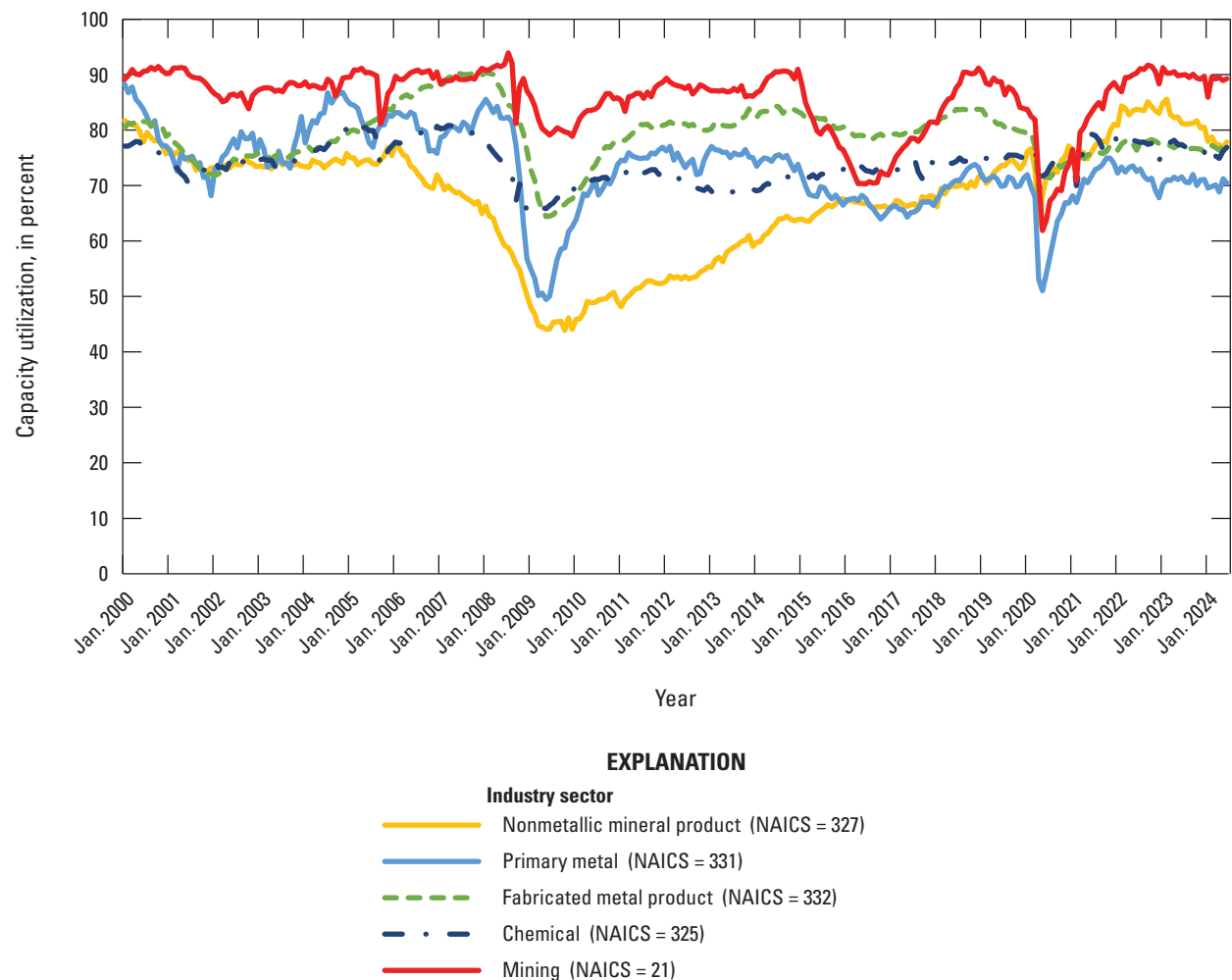


Figure 1. Industrial capacity utilization in the United States for 2000 through 2024; data are from Federal Reserve (2024). NAICS, North American Industry Classification System.

Methodology and Data Collection

Annual world mineral production data for 2018 through 2022 are primarily from published USGS Minerals Yearbook chapters and are provided in the accompanying data release (Alonso and others, 2025). Production data for 2024 and previous years, where unavailable from the Minerals Yearbook chapters, are based on estimates published by the USGS in the Mineral Commodity Summaries (U.S. Geological Survey, 2020, 2021, 2022, 2023, 2024, 2025).

Current capacity data are collected from annual mine- and country-level operating production and capacity data based on reports from companies, governments, and industry sources. Currently producing mines and facilities are considered operating capacity. In some cases, generally owing to poor market conditions, producers decide to idle but not fully shut down a production site. Instead, they put a facility on care-and-maintenance status or pause production on a particular production line. In those cases,

the production capacity is deemed idled capacity. The sum of operating and idled capacity equals the total current estimated production capacity.

The USGS reconciled any identified discrepancies between reported capacity and production by selecting the larger value of these two on the basis of the assumption that capacity should be larger than production. For some facilities, this may be an overestimate, such as cases where production facilities were pushed to operate above reported capacity. However, over time and at the country level, this assumption should be reasonable because operating above capacity is not likely across many mines or for a significant period. Where capacity data were not available, the reported production value was used to calculate the current operating capacity rate. This second assumption would, in general, underestimate capacity because most facilities operate at less than 100 percent.

For the outlook part of the report, capacity adjustments were made for each year based on (1) announced expansions of existing mines, (2) developments of new mines with bankable or definitive feasibility studies, and (3) reported mine

closures to calculate world mineral capacity outlooks through 2029 (Alonso and others, 2025). [Development timelines, reported by mining companies, are often delayed by factors including environmental, financing, infrastructure, permitting, and social issues. Some reported development dates may have been adjusted in anticipation of development delays.] Future capacity may be producing or idled but is not distinguished in this study because this analysis does not attempt to predict market conditions for determining future operation status.

Mathematically, world production capacity (W) of mineral i in year t was calculated by summing production capacity across n producing countries (j), as follows:

$$W_{i,t} = \sum_j^n (O_{i,j,t-1} - C_{i,j,t} + E_{i,j,t} + D_{i,j,t}), \quad (1)$$

where

- i is the mineral or material being examined;
- t is the year being estimated;
- j producing country;
- n is the number of mineral producing countries;
- $O_{i,j,t-1}$ represents the estimated operating production capacity of mineral or material i in country j during the previous year ($t-1$);
- $C_{i,j,t}$ is the expected decrease in production capacity owing to announced closures and other factors in year t for country j ;
- $E_{i,j,t}$ represents the expected increase in production capacity owing to reported expansions and other factors in year t for country j ; and
- $D_{i,j,t}$ represents the increase of production capacity owing to development in year t for country j .

The data collected for this report primarily consist of annual mine- (or country-) level production, capacity, and utilization rates and planned production, development, expansion, and closure reported by companies, governments, and industry sources. Given the short-term focus of this report, exploration or development projects without a bankable or definitive feasibility study are not included regardless of whether the company has made detailed production projections.

Mineral Outlook Through 2029

Cobalt

Cobalt concentrates are often processed into intermediate products, which are then refined into chemical compounds or metal (Shedd, 2024). Chemical compounds comprise most of the global cobalt market, by contained cobalt volume, through their use in lithium-ion battery cathode materials, the primary end use for cobalt. Lithium-ion batteries have become the leading type of battery used in EVs. Other uses for lithium-ion batteries include energy storage systems, electronics, and power tools. Alternatives, such as low-cobalt and cobalt-free cathodes do exist, with substitution motivated by high cobalt prices. Superalloys are the second largest application where cobalt is used as one of many alloying elements in corrosion-resistant, high-temperature, applications such as industrial gas turbine and jet engines.

U.S. efforts to establish domestic cobalt mining and processing are expected to be strengthened through incentives in the Bipartisan Infrastructure Law (BIL; Infrastructure Investment and Jobs Act; Public Law 117–58, 135 Stat. 429), the Inflation Reduction Act (IRA; Public Law 117–169, 136 Stat. 1818), and applications of the Defense Production Act of 1950 (DPA; Public Law 81–774, 64 Stat. 798). Though multiple North American cobalt mining and processing projects are in development, some have stalled owing to the current cobalt price environment.

Globally, the majority of cobalt supply is profitable at current prices (S&P Capital IQ, 2024). The Democratic Republic of the Congo (Congo [Kinshasa]) is the world's leader in cobalt mining (fig. 2); however, companies owned or controlled by China accounted for most of the cobalt production in Congo (Kinshasa) (Gulley, 2024; Darton Commodities Ltd., 2025). New projects and expansions of existing mines in Congo (Kinshasa) and Indonesia are expected to continue to drive increases in mined cobalt production. These companies also have large offtake agreements resulting in significant exports of cobalt from the mining countries to China (Gulley, 2024) where cobalt ore is refined into cobalt chemicals and cobalt metal. Although most of China's refined cobalt production is used in domestic downstream manufacturing (especially batteries), anecdotal evidence suggests that some of it is being stockpiled (Wang, 2024). Higher mine production led to a market surplus in the past 2 years, resulting in a 46-percent decrease in the average cash price on the London Metal Exchange (LME) from 2022 to 2023, reducing incentives for new capacity (fig. 3) to come online (Argus Media, 2024). New projects and expansions of existing mines in Congo (Kinshasa) and Indonesia are expected to continue to drive increases in mined cobalt production.

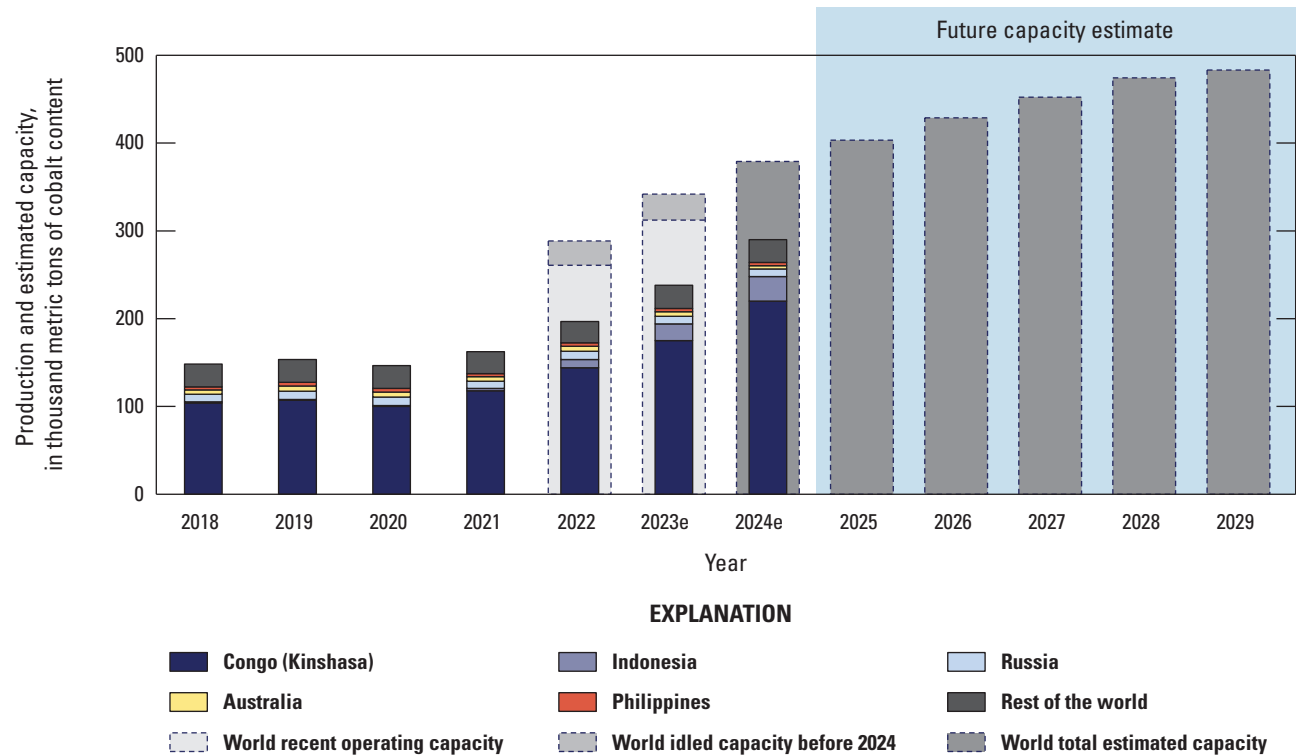
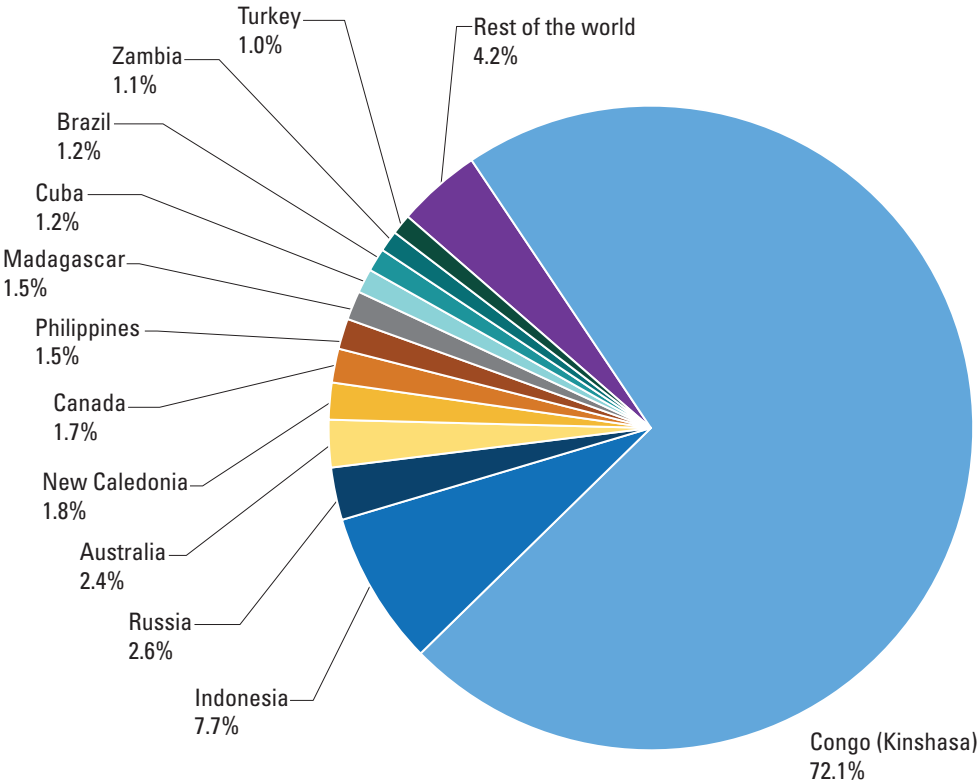


Figure 2. Recent and estimated production and outlook capacity of mined cobalt in thousand metric tons, cobalt content, by country, for 2018 through 2029. Countries that have cobalt mine capacity include Australia, Botswana, Brazil, Cameroon, Canada, China, Congo (Kinshasa), Cuba, Finland, Indonesia, Madagascar, Mexico, Morocco, New Caledonia, Papua New Guinea, Philippines, Russia, South Africa, Turkey, United States, Vietnam, Zambia, and Zimbabwe. Data are from Alonso and others (2025). e, estimated data.

Figure 3. Potential capacity, by country, of cobalt mine production, estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.



Gallium

Gallium is primarily used in the semiconductor industry where it is combined with other elements in a family of materials known as compound semiconductors (Jaskula, 2024b). Although silicon wafers are the predominant material in the semiconductor market, gallium-containing compound semiconductors play an important role in applications where wide-band gaps and high-temperature operation are vital. Examples include light-emitting diodes (LEDs), power-integrated circuits, solar photovoltaics, and transistors, which are then used in communication devices, electricity generation, medical equipment, and transportation applications. More recently, growth in demand for gallium semiconductors has been increasingly tied to the adoption of EVs and the deployment of 5G wireless networks. Gallium is also used as an alloying element in neodymium-iron-boron magnets as well as research and development applications.

The United States is entirely import-reliant for all gallium used domestically, although a single U.S. refinery recovers and recycles new scrap and imported low-purity gallium (Jaskula, 2024a, b). Recent analysis of the U.S. supply risks related to gallium estimated the total U.S. production capacity for high-purity and secondary refined gallium to be 20,000 kilograms (Nassar and others, 2024).

China is the predominant world producer and refiner of gallium (fig. 4). In 2023, China imposed new export controls on the material ([China] Ministry of Commerce, 2023) and followed up with more stringent export restrictions in December 2024 (Kurtenbach, 2024). In 2024, China accounted for 98 percent of global production, but only 87 percent of the global primary low-purity gallium production capacity (fig. 5). The discrepancy is because most of the capacity outside of China is operating at low utilization rates or is on care-and-maintenance status and hence idled. There is not much planned growth in production capacity. However, it is possible that the export controls may result in idled capacity outside of China coming online again.

Helium

Helium is a light, inert gas that is liquid only at very low temperatures owing to a very low boiling point. It is used in applications where these properties are desirable, such as for balloons and dirigibles, magnetic resonance imaging (MRI) coolants, research, aerospace, and welding. Although substitution is challenging owing to helium's unique properties, recycling is possible in many applications by adding a closed-loop collection system to avoid loss to the atmosphere. Even though the quantity of supplies from the closed-loop recycling is not easy to measure, it helps to add resiliency to the helium supply chain.

Helium is largely extracted as a byproduct of natural gas (Goodin and Hamak, 2024). There are some cases where helium is extracted as the main product or coproduced with nitrogen. Some quantities of helium are also obtained from recycling and stockpiles provide market flexibility over time when supply and demand differ significantly. Only a portion of the helium extracted with natural gas is refined, and refining capacity determines most of the primary production capacity. The United States and Qatar are the world's leading producers, and both countries export helium (fig. 6).

Supply chain issues have affected helium availability over the past 15 years. Transporting and delivering helium involves complex logistics because helium requires large specialty containers or tankers to keep it compressed at high pressures or, in the case of liquid helium, at extremely low temperatures. Moreover, those tankers and containers must make the trip back to the refineries to be refilled, adding to the logistical challenges. In 2017, disputes with Saudi Arabia affected Qatar's ability to export helium to global markets (Butler, 2017). As a result, Qatar needed to establish new and more complex routes through Oman. More recently, explosions, fires, and the conflict in Ukraine have caused delays in the development of Russia's Amur helium refinery project but is still expected to add significant global capacity (fig. 7), which was expected to predominantly feed the Chinese market (Kornbluth, 2023; TASS Russian News Agency, 2023).

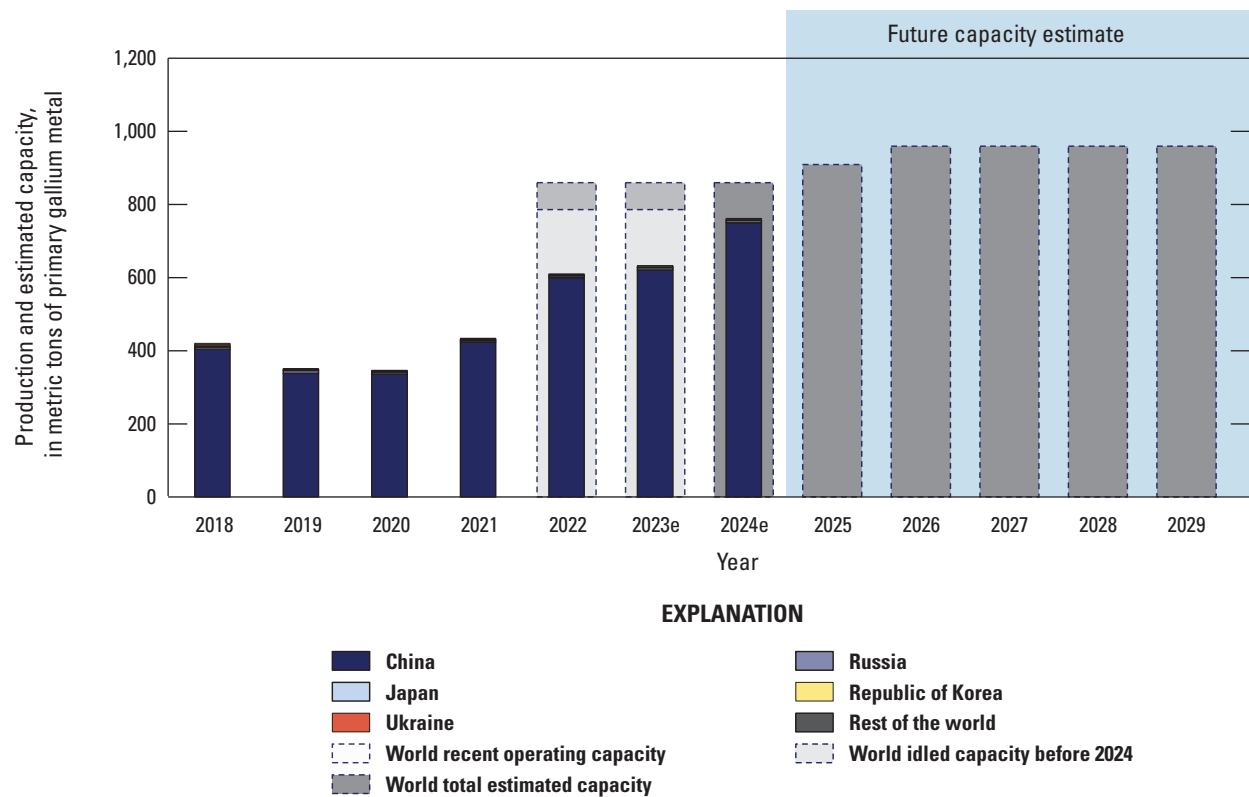
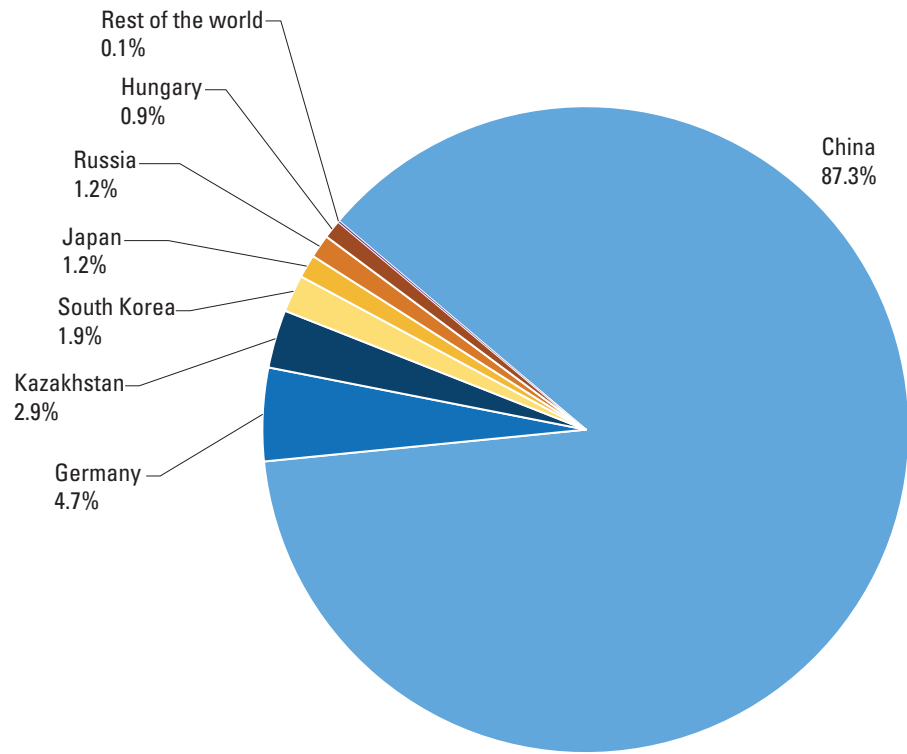


Figure 4. Recent and estimated production and outlook capacity of low-purity primary gallium, in metric tons, by country, for 2018 through 2029. Countries that have gallium primary production capacity include Canada, China, Germany, Hungary, India, Japan, Kazakhstan, Russia, Slovakia, South Korea, Ukraine, the United Kingdom, and the United States. Data are from Alonso and others (2025). e, estimated data.

Figure 5. Potential capacity, by country, of low-purity primary gallium production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.



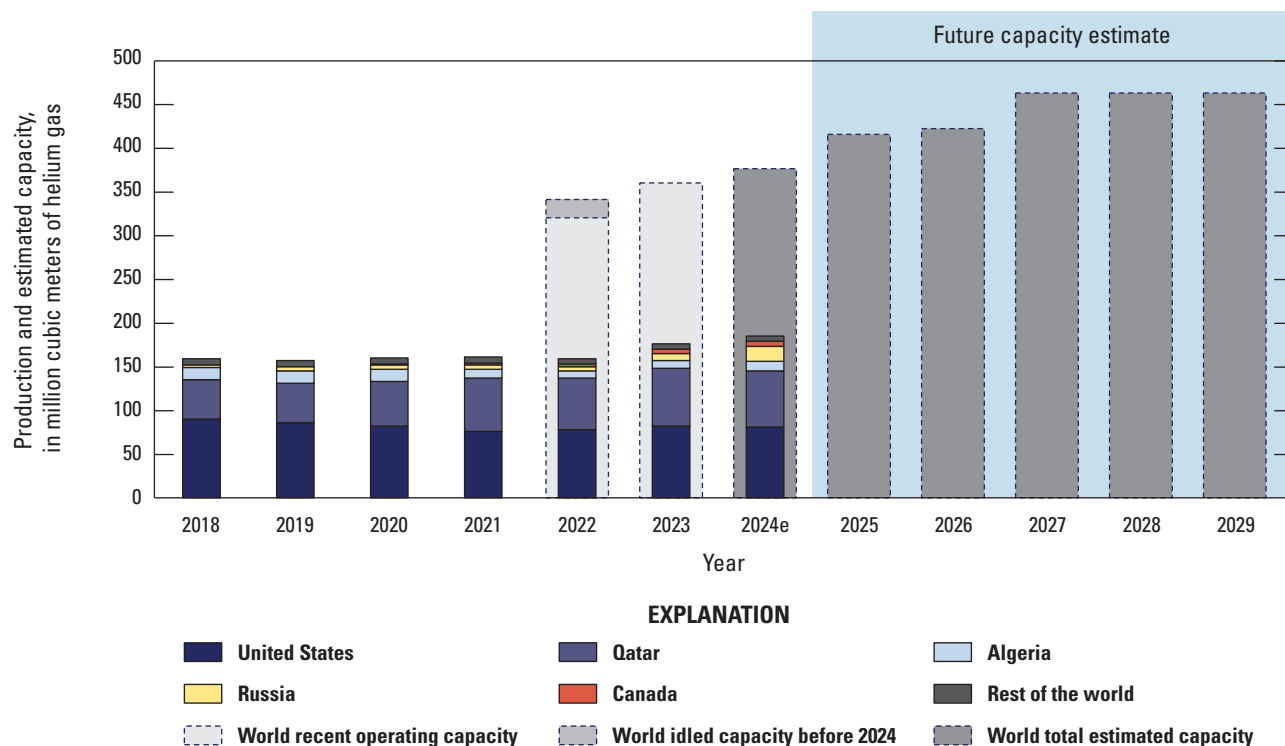


Figure 6. Recent and estimated production and outlook capacity of helium, in million cubic meters, by country, for 2018 through 2029. Countries that have helium production capacity include Algeria, Australia, Canada, Poland, Qatar, Russia, South Africa, and the United States. Data are from Alonso and others (2025). e, estimated data.

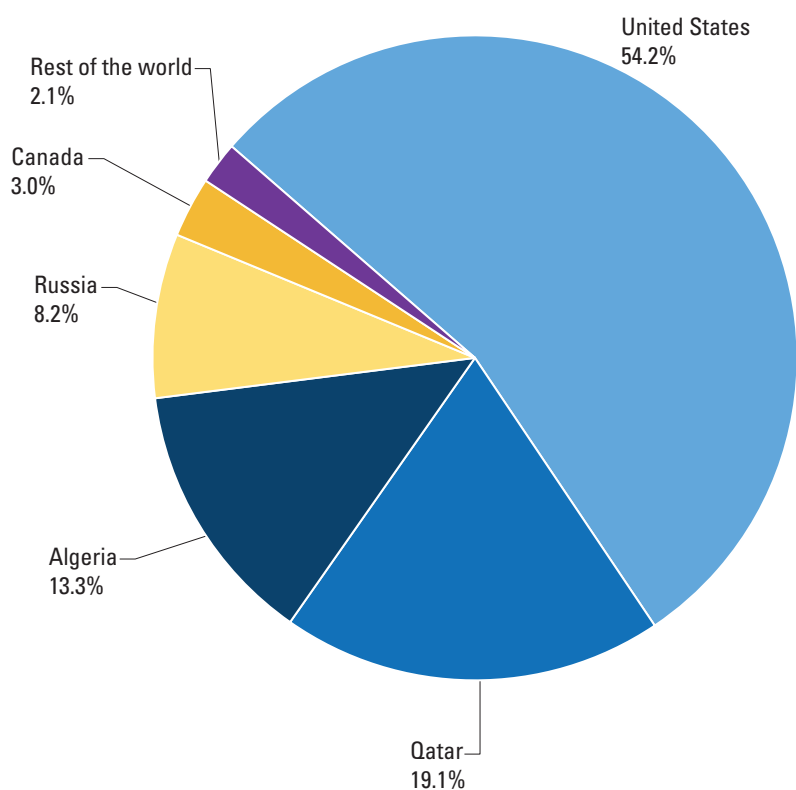


Figure 7. Potential capacity, by country, of helium refinery production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.

Lithium

Batteries are the principal end use for lithium, accounting for 87 percent of usage (Jaskula, 2024c). Air treatment, ceramics, glass, grease, and other uses make up the remainder. Rechargeable lithium-ion batteries are the main battery type for lithium, although non-rechargeable lithium batteries are used in niche applications. Lithium-ion battery demand has grown rapidly over the past decade and is expected to continue to increase owing to rising demand for EVs and energy storage systems (International Energy Agency, 2024).

Lithium is produced from brines and hard rock ores which are then processed into compounds such as lithium carbonate, hydroxide, and chloride. The United States imports lithium products but also produces lithium commercially from brine sources. In anticipation of rising demand for lithium-ion batteries, especially those used in EVs, mining companies have invested in the expansion of lithium production (figs. 8 and 9). Although not included in the timeframe covered for this outlook, between 2016 and 2018, lithium production in Australia quadrupled as five mines ramped up production. Currently, hard rock ores in Australia are the main source of lithium worldwide (fig. 8). Chile is the world's second-largest producer, drawing from lithium brines.

Magnesium Metal

The magnesium market is split into magnesium metal and magnesium compounds; this report only considers magnesium metal. Magnesium metal is desired for its high strength-to-weight ratio. Magnesium metal is used in aluminum alloys, die casting, metal desulfurization, metal reduction, nodular cast iron, and other applications. Within the die-casting segment, magnesium is used in the aerospace and automotive sectors, in consumer goods, medical devices, and in sporting equipment (Bray, 2024).

A single producer in the United States produces magnesium metal from brine, but the production number was withheld to avoid disclosing company proprietary information. However, the production capacity value was included in the outlook because it is reported on the company's website (US Magnesium LLC, 2024). The United States also has secondary production capacity for magnesium metal from recycled metal, and this value has been used for the capacity shown in figure 10.

Overall, world production of primary magnesium metal has been relatively flat from 2018 to 2024. China dominates the production of magnesium metal and global production capacity. Other producing countries include Brazil, Iran, Israel, Kazakhstan, Russia, Turkey, and Ukraine, each with less than a 3-percent share of world production. The global future capacity for magnesium metal is not expected to grow. About half of China's capacity is idled at least some of the time, and any proposed capacity expansions are highly uncertain (fig. 11). Many of the magnesium projects outside of China cannot compete with China owing to the country's access to low-cost fuel, large deposits of dolomite, and government support. As a result, non-Chinese projects lose funding or encounter other technical and economic obstacles before construction is completed (Project Blue, 2024).

Palladium

Palladium is a platinum-group metal (PGM) predominantly used in automobile and truck catalytic converters (especially for gasoline-based engines) as well as capacitors, chemical production, dental alloys, integrated circuits, jewelry, and petroleum refining (Schulte, 2024). Rising adoption of EVs could reduce demand for palladium since EVs do not have a catalytic converter. This development may reduce future palladium production unless other end-use sectors increase consumption to balance the projected downturn in demand caused by EVs. Palladium is mined from two deposits in Montana by one company. One of those mines was recently put on care-and-maintenance status as the company restructured its operations owing to the decreasing price of palladium. The PGM deposits in the United States have higher concentrations of palladium than platinum. However, the palladium mined in the United States is sent overseas to be refined. Secondary palladium is also refined and recycled domestically along with other PGMs.

Globally, mine production and primary refining are concentrated in South Africa and Russia (fig. 12). Despite recent improvements (Habershon, 2024), South Africa's long history of uncertainty in the supply of electricity will likely continue to affect the country's PGM production. Russia's 2023 palladium production was estimated to have increased from that in 2022 and 2021 (fig. 13). Both countries have abundant reserves and are expected to continue contributing significantly to future installed capacity given an outlook where future capacity remains flat. Recycling is also an important source of palladium, but statistics on the availability of secondary palladium are difficult to track owing to the closed-loop nature of recycling.

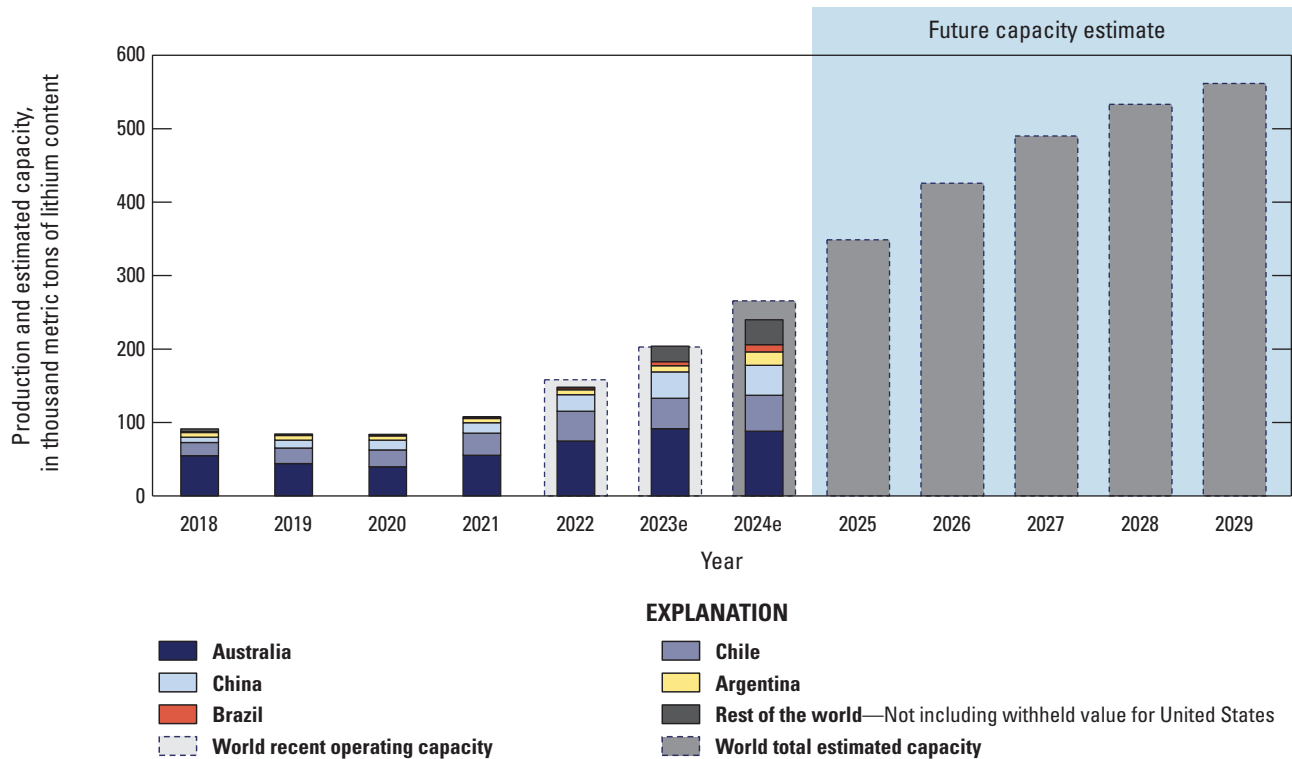


Figure 8. Recent and estimated production and outlook capacity of lithium content in thousand metric tons, by country, for 2018 through 2029. Countries that have lithium production capacity include Argentina, Australia, Austria, Bolivia, Brazil, Canada, Chile, China, Czechia, Congo (Kinshasa), Ethiopia, Finland, France, Germany, Ghana, Mali, Mexico, Namibia, Nigeria, Peru, Portugal, Russia, Rwanda, Serbia, South Africa, Spain, the United Kingdom, and Zimbabwe. Data are from Alonso and others (2025). e, estimated data.

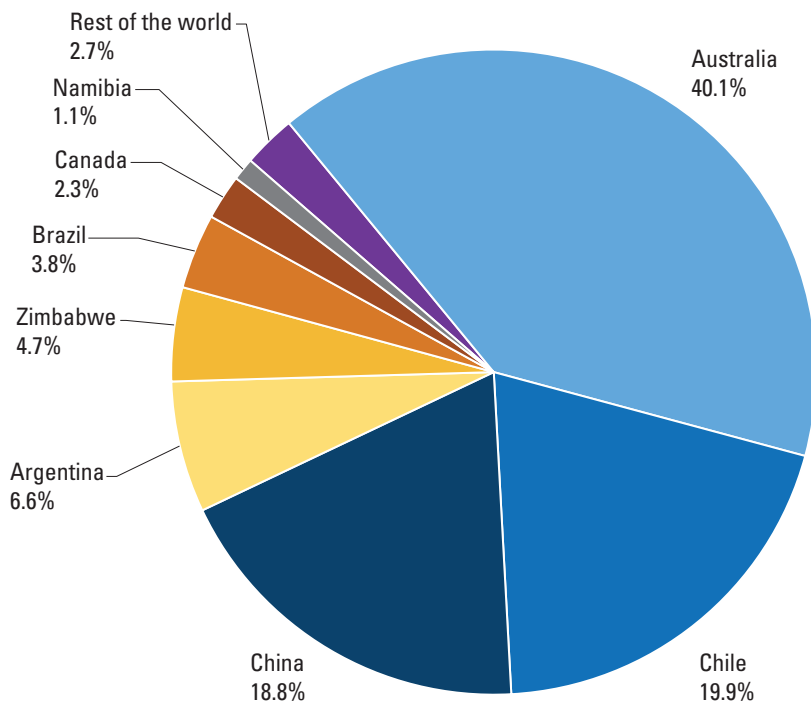


Figure 9. Potential capacity, by country, of lithium primary production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.

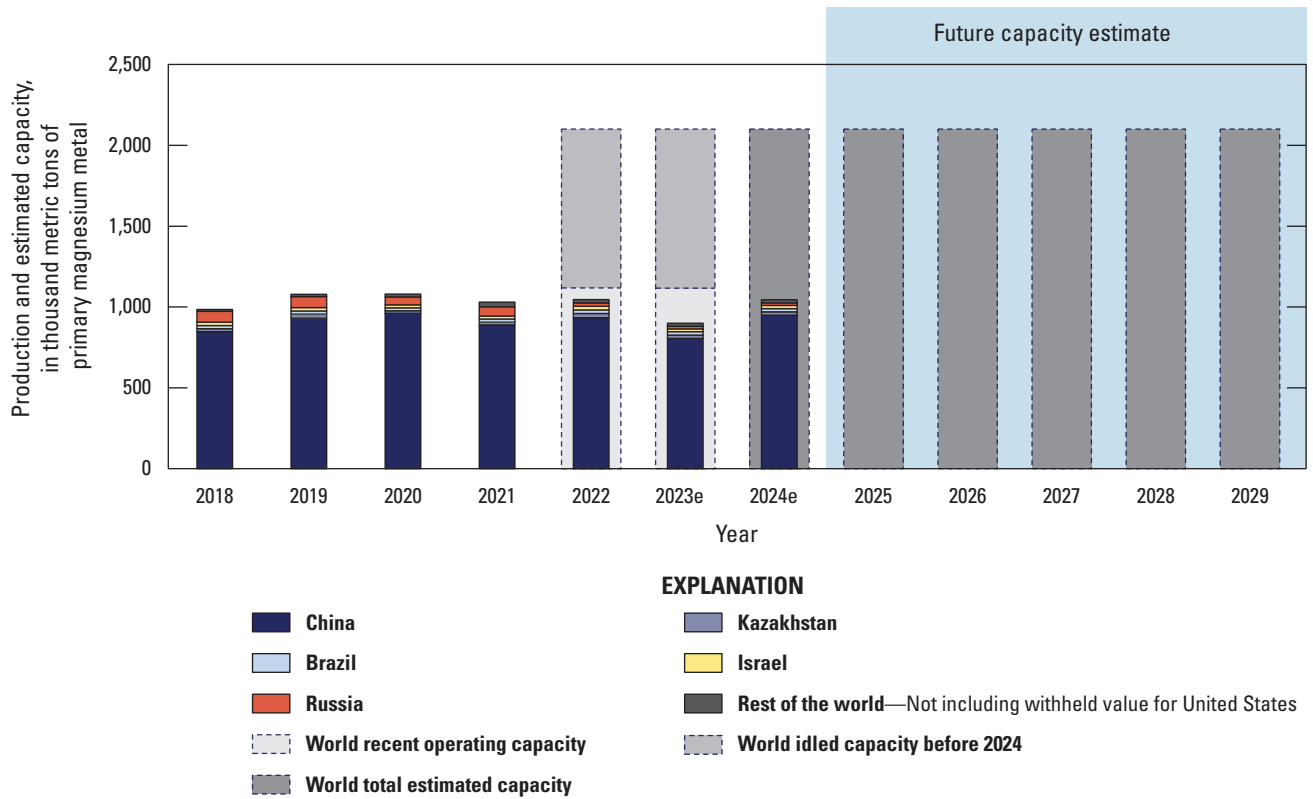
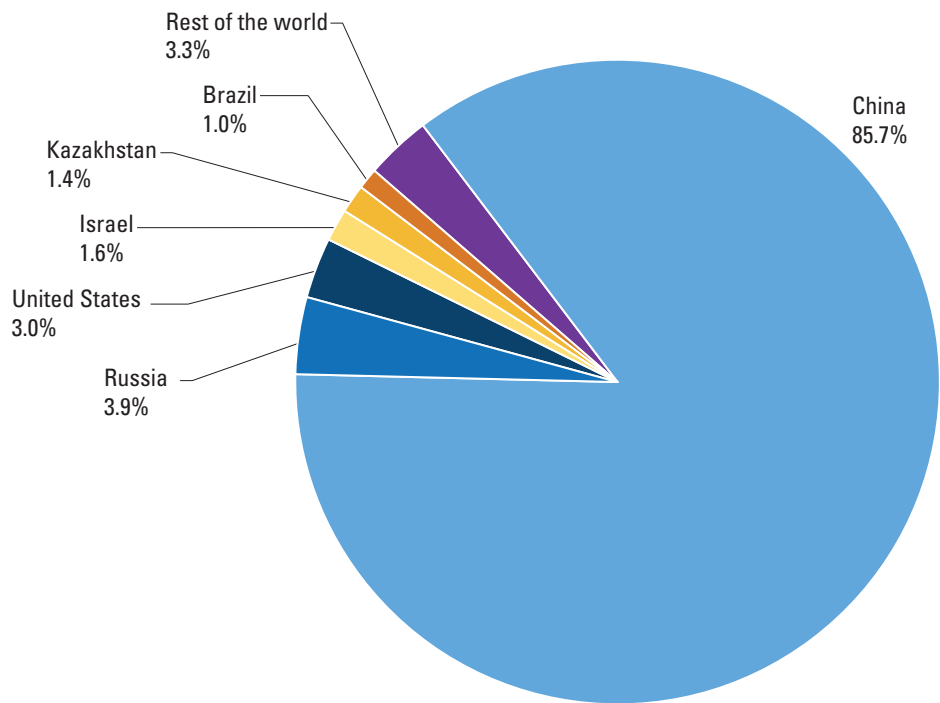


Figure 10. Recent and estimated production and outlook capacity of primary magnesium metal in thousand metric tons, by country, for 2018 through 2029. Countries that have magnesium production capacity include Australia, Brazil, Canada, China, Iran, Israel, Kazakhstan, Malaysia, Russia, Serbia, South Korea, Turkey, Ukraine, and the United States. Data are from Alonso and others (2025). e, estimated data.

Figure 11. Potential capacity, by country, of magnesium primary production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.



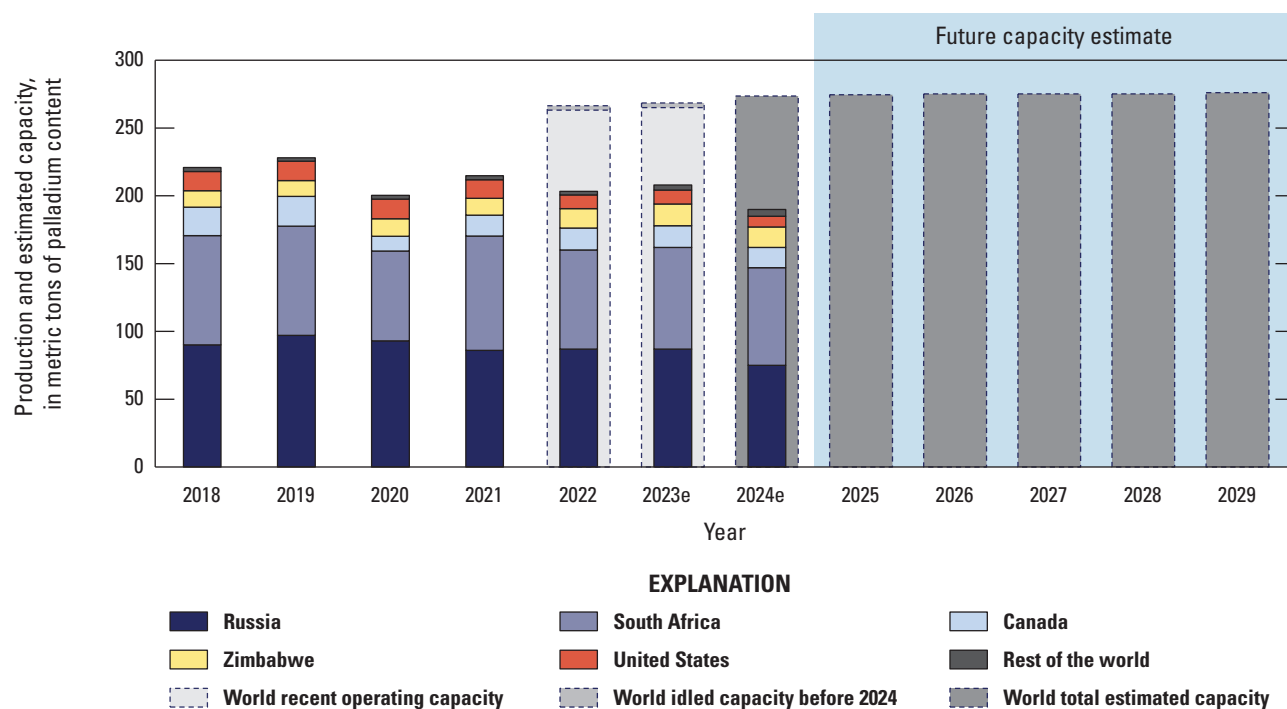


Figure 12. Recent and estimated mine production and capacity outlook of palladium, in metric tons, palladium metal content, by country, for 2018 through 2029. Countries that have palladium production capacity include Australia, Canada, China, Finland, Russia, Serbia, South Africa, the United States, and Zimbabwe. Data are from Alonso and others (2025). e, estimated data.

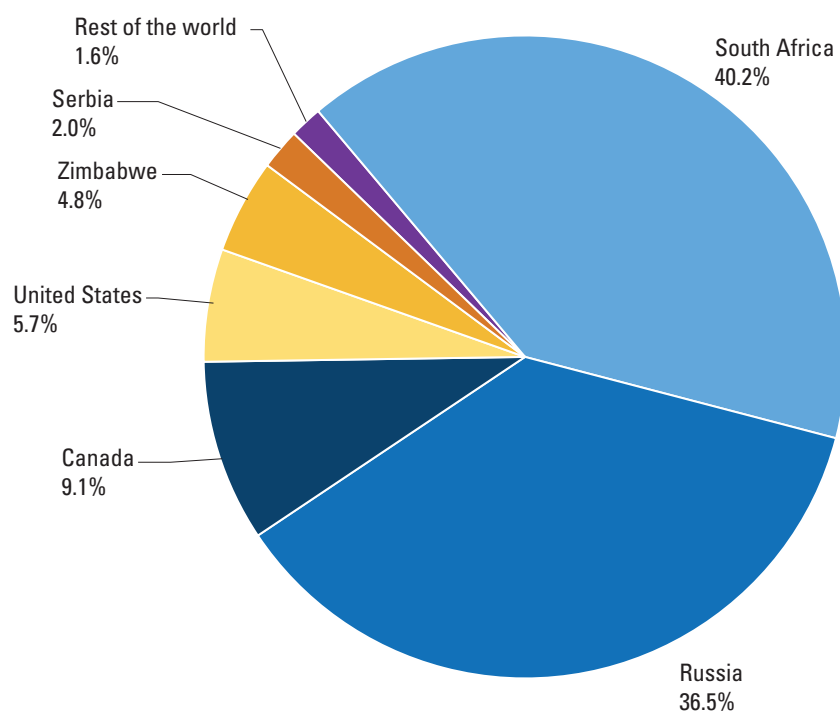


Figure 13. Potential capacity, by country, of palladium mine production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.

Platinum

Platinum is used in automobile and truck catalytic converters (especially for diesel-based combustion engines), as well as chemical production, dental alloys, hard disk drives, industrial thermocouples, jewelry, petroleum refining catalysts, and medical devices (Schulte, 2024). An emerging application of platinum is in proton exchange membrane fuel cells, one of many technologies that could be implemented in a low-carbon future. However, the rate of adoption for fuel cell technologies is uncertain given the uptake in lithium-ion batteries for EVs and energy storage. Platinum is mined from two deposits in Montana by one company (fig. 14). Operations are expected to continue but various cost reduction measures have been put in place, including putting one of the mines on care-and-maintenance status (Sibanye Stillwater Ltd., 2024). The platinum mined in the United States is sent overseas to be refined. The PGM deposits in the United States contain platinum in lower concentrations than palladium. Secondary platinum is also refined and recycled domestically along with other PGMs.

More so than palladium, platinum mine production is highly concentrated in South Africa (fig. 15). However, as with palladium, recent efforts to stabilize the power supply will likely improve platinum supply stability. Recycling is highly dependent on the price of platinum. Additionally, vehicle retirements, a major source of recycled platinum, have trended down recently, thereby reducing the amount of platinum available for recycling.

Titanium Sponge Metal

The global market for titanium can be broken down into coatings, chemicals, titanium dioxide and titanium sponge metal segments. This report only considers titanium sponge metal. Titanium sponge metal is used primarily in the aerospace industry. Other significant consuming industries include consumer goods, chemical process, medical, power generation, and metallurgy applications.

In 2023, the United States had one active producer of titanium sponge metal with limited production capacity dedicated to serving the electronics industry. Previously, two producers idled sponge facilities, which caused an increased reliance on imports from Japan and elsewhere to support the domestic supply chain. The production value has been withheld in this report (fig. 16) to avoid disclosing proprietary information. World titanium sponge production has been steadily increasing over the past few years, primarily from capacity expansions in China (fig. 17). China was the top global producer with a 67-percent share of world output in 2023 (U.S. Geological Survey, 2025). Other notable producing countries include Japan, Kazakhstan, Russia, and Saudi Arabia while operations in Ukraine were idle owing to the conflict with Russia (fig. 17).

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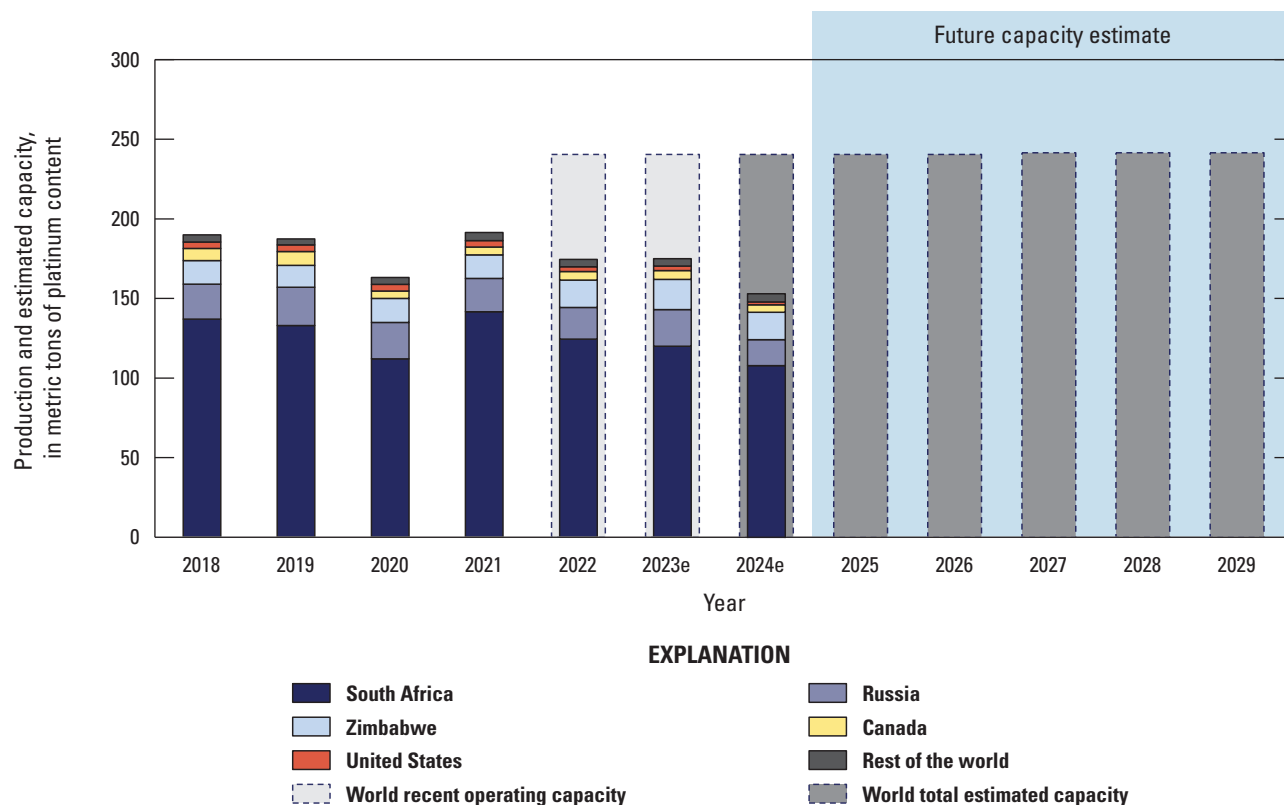


Figure 14. Recent and estimated mine production and capacity outlook of platinum, in metric tons, platinum metal content, by country, for 2018 through 2029. Countries that have platinum production capacity include Australia, Canada, China, Colombia, Ethiopia, Finland, Russia, Serbia, South Africa, the United States, and Zimbabwe. Data are from Alonso and others (2025). e, estimated data.

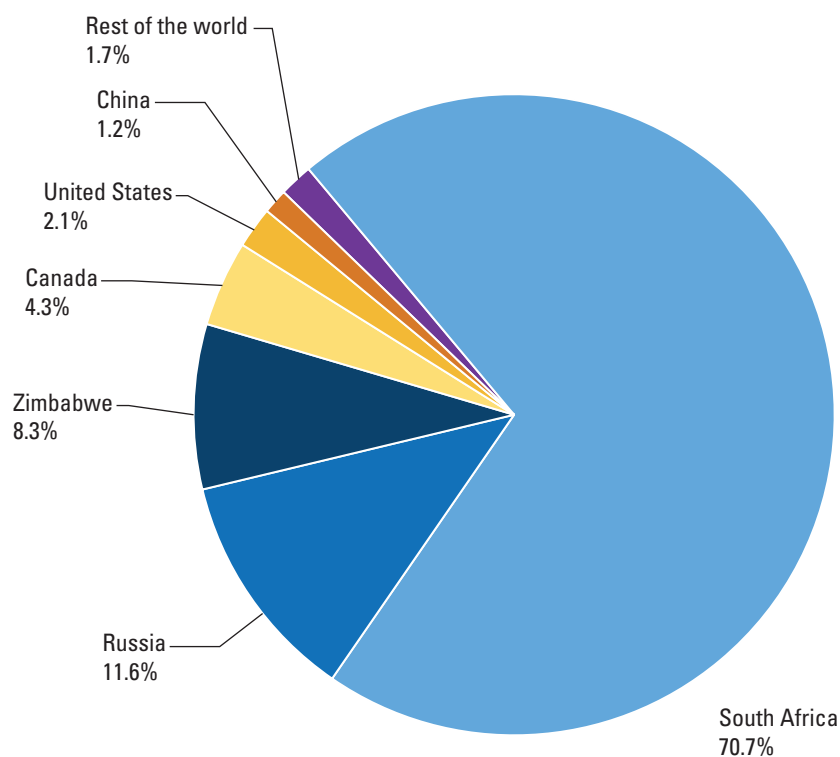


Figure 15. Potential capacity, by country, of platinum mine production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.

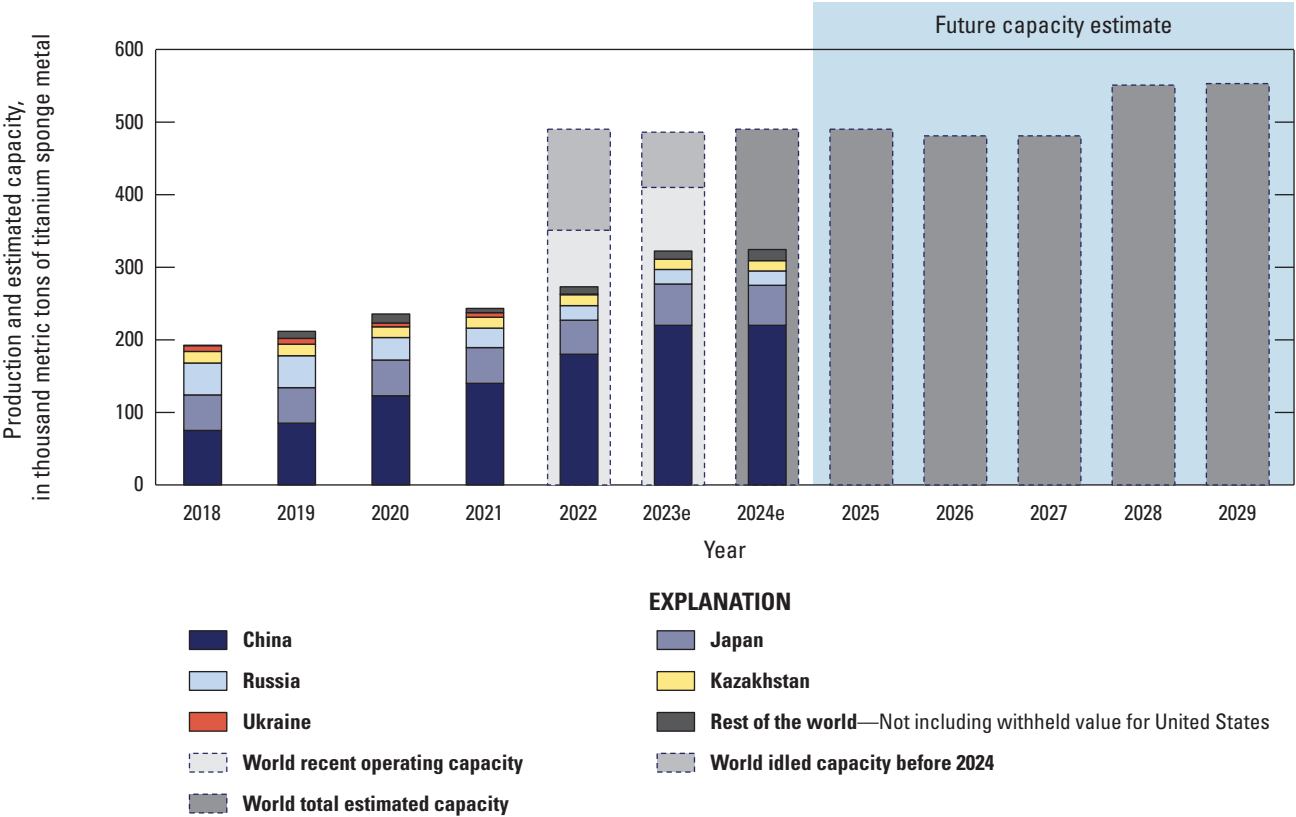
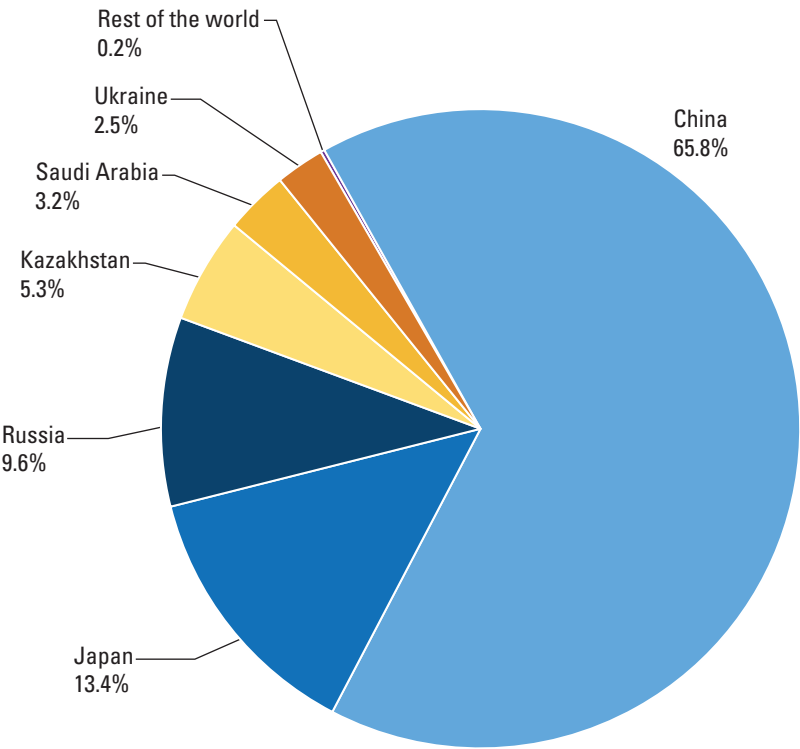


Figure 16. Recent and estimated mine production and capacity outlook of titanium sponge (metal), in thousand metric tons, by country, for 2018 through 2029. Countries that have titanium sponge refining and production capacity include China, India, Japan, Kazakhstan, Russia, Saudi Arabia, Ukraine, and the United States. Data are from Alonso and others (2025). e, estimated data.

Figure 17. Potential capacity, by country, of titanium sponge (metal) production estimated for 2024. All capacity status (operating, expansion, care-and-maintenance, and expected new capacity) is included. Data are from Alonso and others (2025). %, percent.



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