



2022 Minerals Yearbook

COBALT [ADVANCE RELEASE]

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COBALT

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In 2022, cobalt was mined in the United States as a byproduct of nickel and copper production in Michigan and recovered from tailings generated by previous mining of lead and other metals in Missouri. Cobalt also was recovered in negligible amounts as an intermediate nickel compound from the mining and refining of platinum-group-metal (PGM) ore in Montana. The total quantity of U.S. cobalt production was an estimated 500 metric tons (t), a 23% decrease from that in 2021 (table 1).

In 2022, world production of mined cobalt increased by 21% to 197,000 t owing mostly to increased production at multiple operations in Congo (Kinshasa) and new production in Indonesia. Congo (Kinshasa) remained the leading producer of mined cobalt, accounting for 73% of world production (tables 1, 7).

The United States did not refine cobalt ores or concentrates in 2022. World production of refined cobalt was 174,000 t, a slight increase from 171,000 t (revised) in 2021. China remained the leading producer of refined cobalt, accounting for 80% of the world total (tables 1, 8).

In 2022, U.S. apparent consumption of cobalt was 7,060 t, a 6% increase from that in 2021. The increase was due to an increase in net imports for consumption (tables 1, 2). Globally, world consumption of refined cobalt increased in 2022 from that in 2021 owing largely to an increase in cobalt consumption in rechargeable batteries for electric vehicles (EVs), partially offset by a decrease in consumption in rechargeable batteries for portable electronics. Analysts noted that cobalt demand growth slowed in 2022 compared with that in 2021 owing in part to an increasing market share of low- or no-cobalt battery chemistries for EVs. Cobalt supply-demand scenarios by multiple analysts showed that mined and refined cobalt was in a surplus at yearend 2022 (Darton Commodities Ltd., 2023, p. 30, 45, 59–61; Desai, 2023; Yu, 2023).

Cobalt is a metallic element used in numerous diverse commercial, industrial, and military applications. Globally, beginning in 2021, the leading use of cobalt was lithium-ion batteries for EVs. The second-ranked use in 2022 was in other lithium-ion battery applications such as drones, energy storage, laptops and tablets, and mobile phones. The third-ranked use was superalloys, which were used to make parts for gas turbine engines. Other metallurgical uses for cobalt included cemented carbides (also called hardmetals) and diamond tools, controlled-expansion and corrosion- and wear-resistant alloys, high-speed and maraging steels, and magnets. Other chemical uses for cobalt included animal feed additives; catalysts in the chemical and petroleum industries; drying agents for inks, paints, and varnishes; dyes and pigments; glass decolorizers; ground coats for porcelain enamels; humidity indicators; magnetic recording media; rubber adhesion promoters for steel-belted radial tires; and as a component of vitamin B12 (Project Blue Grp. Ltd., The, 2022a, p. 1, 12–13; Cobalt Institute, 2023, p. 13; Darton Commodities Ltd., 2023, p. 33).

Government Actions and Legislation

Critical minerals are defined as nonfuel minerals or mineral materials essential to the economic and national security of the United States, the supply chain of which are vulnerable to disruption, and that serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the U.S. economy or national security. In February, the U.S. Geological Survey (USGS) published the 2022 final list of critical minerals in the Federal Register (87 FR 10381). The 2022 list revised the final list published in 2018 (83 FR 23295) based on an updated assessment that utilized enhanced methodology. Cobalt was included in the 2018 list as well as the revised 2022 list, which contained a total of 50 critical minerals (U.S. Department of the Interior, Office of the Secretary, 2018; U.S. Geological Survey, 2022).

On March 31, 2022, President Biden issued a Presidential determination (No. 2022–11) allowing the U.S. Department of Defense (DOD) to use Defense Production Act title III authorities to increase domestic production of critical materials, including raw cobalt or refined products, through mining, processing, recycling, reuse, and recovery. DOD actions could include but were not limited to undertaking feasibility studies, modernization projects, or byproduct or coproduct production at existing mining sites. The Presidential determination followed a February 2022 DOD evaluation of the defense industrial base that found increased reliance on too few contractors for multiple priority sectors including energy storage and batteries (which contain cobalt) and strategic and critical minerals, including cobalt (U.S. Department of Defense, 2022a; 2022b, p. 1–2, 17–23).

The Inflation Reduction Act of 2022 (IRA) became Public Law 117–169 on August 16, 2022. This law included multiple funding and tax programs to stimulate domestic production, processing, manufacturing, and recycling of critical minerals including cobalt. Key features of the law included consumer tax credits for EVs with batteries containing critical minerals that meet domestic sourcing requirements, and loans and tax credits for the domestic production and sale of vehicle components that include critical minerals (White House, The, 2023, p. 10, 30, 46–50).

In 2022, multiple cobalt projects were funded through the Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act, H.R. 3684, Public Law 117–58) passed in 2021. The U.S. Department of Energy (DOE) awarded a total of \$576 million for recycling projects focused on recovering cobalt and other metals from lithium-ion battery scrap for use in the manufacture of new lithium-ion batteries. The funded projects were proposed by Ascend Elements Inc., Cirba Solutions, Nth Cycle, and Princeton NuEnergy. The DOE also awarded \$114 million to Talon Metals Corp. for the construction of an ore-processing facility in North Dakota that would produce cobalt in nickel concentrate from nickel ore mined at the company's Tamarack Mine in Minnesota. Talon's Tamarack

Mine was under development at yearend 2022. Talon completed a preliminary economic assessment for the project in 2021 and an updated resource assessment in 2022 (Ascend Elements Inc., 2022; Cirba Solutions, 2022a, b; Nth Cycle, 2022; Princeton NuEnergy, 2022; Talon Metals Corp., 2022a, p. 1; 2022b; U.S. Department of Energy, 2022a, p. 8–10, 22; 2022b, p. 3, 6).

The U.S. Department of Labor added lithium-ion batteries to its 2022 list of goods produced by child labor or forced labor. The 2022 list was expanded to include final products with inputs that are made with child labor or forced labor. Previous lists, the last of which was published in 2020, included only final goods made with child or forced labor. Chinese produced lithium-ion batteries were added to the list in 2022 as a downstream good made with cobalt produced with the use of child labor in artisanal and small-scale mining in Congo (Kinshasa) (U.S. Department of Labor, 2022a, p. V, 17, 44, 51).

In 2022, the U.S. Department of Labor concluded the Combatting Child Labor in the Democratic Republic of the Congo's Cobalt Industry project which aimed to strengthen Government and stakeholder efforts to combat child labor in the cobalt supply chain. The project operated in Lualaba and Haut-Katanga Provinces encompassing Kolwezi and nearby mining sites, Likasi and nearby mining sites, Kambove, Lubumbashi, and Kipushi. The project identified and connected various projects, initiatives, and interventions that were already underway, established strategies and roadmaps to coordinate these efforts, and initiated the development of a child labor monitoring system (U.S. Department of Labor, 2022b, p. 5–9, 13–14, 16–20).

Production

In 2022, three companies produced cobalt-bearing ore concentrates in the United States. Estimated U.S. mine production was 500 t, a 23% decrease from that in 2021 (table 1).

Lundin Mining Corp. (Canada) produced copper and nickel sulfide concentrates from the underground Eagle nickel-copper mine, northwest of Marquette, MI, and a mill in Humboldt Township, MI. Eagle's nickel concentrates, which contained cobalt, were transported by rail to be smelted in Canada (Lundin Mining Corp., 2023, p. 18, 55, 57, 61).

U.S. Strategic Metals, LLC (USSM), formerly Missouri Cobalt, LLC, produced a bulk concentrate containing cobalt, copper, and nickel by reprocessing tailings from previous mining of lead and other metals at the Madison Mine near Fredericktown, Madison County, MO. In 2022, the company was constructing a commercial-scale hydrometallurgical plant in Fredericktown that would produce battery-grade cobalt sulfate and nickel sulfate. The plant was designed to process raw ore, mine waste, and lithium-ion battery scrap. In September 2022, USSM announced plans to break ground that month on a battery material pilot plant colocated at the site of the mine and hydrometallurgical facility. The plant would produce cobalt-containing precursor cathode active material for EV batteries from material mined or processed onsite (U.S. Strategic Metals, LLC, 2022; M.R. Hollomon II, Commercial Director, U.S. Strategic Metals, LLC, written commun., May 25, 2023).

Sibanye Stillwater Ltd. (South Africa) produced negligible amounts of cobalt in nickel sulfate at its PGM mining and refining operations in southern Montana (Stillwater Mining Co., 2017, p. 21).

In 2022, Jervois Global Ltd. (Australia) continued construction at its 100%-owned Idaho Cobalt Operations (ICO) project, west of Salmon in Lemhi County, ID. In October, the mine and processing plant were being commissioned. Initial production was expected in 2023. The operation would process approximately 1,090 metric tons per day of cobalt-copper-gold ore from an underground mine during a period of 7 years to produce a bulk concentrate containing 1,915 metric tons per year (t/yr) of cobalt. Through the year, Jervois also completed a bankable feasibility study for the São Miguel Paulista nickel-cobalt refinery (SMP) in Sao Paulo, Brazil, and completed acquisition of 100% ownership of the refinery in July. Jervois anticipated producing refined cobalt at SMP from ICO feedstock and third-party concentrate suppliers. Phase 1 of the SMP restart included production of 2,000 t/yr cobalt metal expected to begin in the first quarter of 2024 (Jervois Global Ltd., 2022a, p. 20, 43, 46, 52; 2022b; 2023, p. 25–28).

In July 2022, PolyMet Mining Corp. entered into an agreement with Teck American Inc. (a subsidiary of Teck Resources Ltd. of Canada) to form a 50–50 joint venture to develop PolyMet Mining Corp.'s proposed open pit mine at the NorthMet copper-nickel-PGM deposit and to study development options for Teck's Mesaba copper-nickel-precious metals deposit. Both projects are in Minnesota's Duluth Complex and reportedly represented approximately one-half of the complex's known resources of cobalt, copper, nickel, and PGMs. Under the agreement, PolyMet Mining Corp. and Teck American Inc. would become equal partners of PolyMet Mining, Inc. (a subsidiary of PolyMet Mining Corp.), which would be renamed NewRange Copper Nickel LLC. During 2022, PolyMet Mining Corp. continued to face legal challenges to various permits and approvals granted for the NorthMet project in 2018 and 2019 from the Minnesota Department of Natural Resources, the Minnesota Pollution Control Agency, and the U.S. Army Corps of Engineers (PolyMet Mining Corp., 2022; 2023, p. 5–7).

U.S. processors produced intermediate or marketable cobalt chemicals from refined cobalt materials and (or) cobalt-bearing scrap. USGS data on chemical and metal powder production, shipments, and stocks were derived from a monthly voluntary survey of U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in tables 1 and 2.

Consumption

U.S. estimated consumption of cobalt in 2022 increased by 5% to 7,650 t from that in 2021 (tables 1, 2). Cobalt consumption by metallurgical industries was estimated to have increased by 8%, and cobalt consumption by chemical industries was estimated to have decreased by 3% from that in 2021. Estimated consumption statistics were derived from the USGS voluntary surveys of U.S. operations. Most of the cobalt chemical-use data were obtained from the cobalt processors survey that included four companies. A second survey covered a broad range of metal-consuming companies, such as cemented carbide, magnetic alloy, and superalloy producers. For this survey, 50 cobalt consumers were canvassed on a monthly or annual basis. Consumption and stock data in tables 1 and 2 include reported data and estimates based on prior reports or industry trends to account for nonrespondents.

U.S. apparent consumption for 2022, as calculated from net imports, consumption from purchased scrap, and changes in industry stocks, increased by 6% from apparent consumption in 2021 (table 1). The increase was a result of increases in net imports for consumption (tables 1, 2).

Prices

The annual average U.S. spot price for electrolytic cobalt (cobalt cathode, minimum of 99.8% cobalt), as reported by S&P Global Platts Metals Week, was \$30.78 per pound, 27% more than that in 2021 (table 1). During 2022, the weekly average spot price generally trended upward into the second quarter and reached a maximum weekly average of \$39.53 in April and May; prices declined through yearend to a low weekly average price of \$19.43 in December.

Cobalt metal with a minimum of 99.8% cobalt in the form of briquets (known as briquettes by the cobalt industry), broken and cut cathode, coarse-grain metal powder, and rounds was traded under a physically settled futures contract on the London Metal Exchange Ltd. (LME). This physically settled contract provided for delivery of physical metal at an agreed time in the future. During 2022, the monthly LME cash mean price peaked at a value of \$36.99 per pound (reported as \$81,539.47 per metric ton) in April, then declined to a low of \$22.27 per pound (reported as \$49,095.00 per metric ton) in August, and remained close to \$23.25 (reported as \$51,260.00 per metric ton) for the rest of the year. The annual average mean of cash buyer and cash seller prices and yearend LME inventory levels are listed in table 1.

Foreign Trade

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic supply to meet demand. Net import reliance is defined as imports minus exports plus adjustments for industry stock changes. Releases from stocks were counted as part of import reliance, regardless of whether they were originally imported or produced in the United States. In 2022, net import reliance as a percentage of apparent consumption for cobalt was 74%. Because U.S. cobalt mine production was exported to be refined, this indicated that 74% of U.S. cobalt supply was from imports and stock releases of refined cobalt and 26% was from purchased scrap.

The cobalt content of U.S. imports and exports was estimated based on gross weight data reported by the U.S. Census Bureau and estimated cobalt content. In 2022, the cobalt content of U.S. imports of metal and chemical compounds was 10,500 t valued at \$597 million, a 7% increase in quantity from the 9,790 t (revised) of material imported in 2021 (table 3). On the basis of cobalt content, six countries supplied 79% of U.S. imports in 2022. Norway was the leading supplier, followed by Finland, Canada, Japan, the United Kingdom, and Russia (table 4).

The cobalt content of U.S. exports of unwrought cobalt and chemical compounds was 5,360 t valued at \$170 million, 9% more in quantity than the 4,930 t exported in 2021 (table 5). On the basis of cobalt content, Canada was the leading destination for these exports, followed by Ireland, the United Kingdom, Germany, and France, each of which imported more than 300 t of cobalt from the United States (table 5).

World Review

In 2022, world cobalt mine production totaled 197,000 t, an increase of 21% compared with revised production in 2021 (table 7). The increase was mainly the result of a 22% increase in estimated production in Congo (Kinshasa), the leading global producer of mined cobalt. World cobalt refinery production was 174,000 t, a slight increase compared with that in 2021 (table 8).

Cobalt was produced as a byproduct of copper, nickel, and other metals, and as a primary product (the principal product of a mining or processing operation). Primary cobalt production included mine and refinery production in Morocco; artisanal mining of the mineral heterogenite (a trivalent cobalt oxyhydroxide mineral) in Congo (Kinshasa); and recovery of cobalt from previously stockpiled intermediate materials [for example, tailings in Congo (Kinshasa)], which were processed primarily to recover cobalt.

Refinery capacity by country is listed in table 6. Depending on vertical integration and the processes used, these plants consumed mainly ores, concentrates, and (or) partially refined intermediate materials; they also may have consumed some secondary (scrap) materials. The table does not include plants that reprocessed refined cobalt, plants that used scrap as their main source of feed, or plants that produced a partially refined intermediate material that required further refining by another plant.

Australia.—At least seven companies mined cobalt as a byproduct from cobalt-bearing nickel ore or from nickel-copper ores in the State of Western Australia. Cobalt mine production increased by 11% from that in 2021 to 5,790 t. Glencore plc's (Switzerland) Murrin Murrin nickel-cobalt laterite mining and refining operation was Australia's leading producer of mined cobalt and the sole producer of refined cobalt, which was in the form of coarse powder and briquettes. In 2022, Murrin Murrin produced 3,300 t of refined cobalt, 18% more than the 2,800 t produced in 2021. Production at the nickel-cobalt refinery in 2022 recovered after maintenance issues and a statutory shutdown hampered production in 2021 (tables 7, 8; Glencore plc, 2023, p. 272).

BHP Group Ltd.'s Nickel West integrated nickel sulfide operation included four mines, colocated concentrators, a smelter, and a nickel refinery that produced cobalt in mixed sulfide precipitate (MSP), an intermediate product. In 2022, production at Nickel West was affected by continued coronavirus disease 2019 (COVID-19) pandemic-related labor shortages and a smelter outage (BHP Group Ltd., 2023, p. 25, 202).

Mincor Resources NL (Western Australia) began production at its Kambalda Nickel Operations in the State of Western Australia by extracting its first ore in December 2021 and processing its first ore at the Kambalda Nickel Concentrator in June 2022. The definitive feasibility study for the Kambalda nickel mines was based on expected annual production of hundreds of tons of cobalt in concentrate during a mine life of 5 years (Mincor Resources NL, 2020, p. 30; 2023, p. 1, 11, 25).

Canada.—In 2022, Canada's cobalt mine production, which was a byproduct of nickel mining, decreased by 23% from that in 2021 to 3,063 t. Canadian production of refined cobalt from domestic and imported concentrates decreased by 4% from that in 2021. The decline in Canada's mine production was largely due to an employee strike at Glencore's

Raglan Mine in the Province of Quebec from May 27 through September 9, 2022. Mining activity at Raglan was part of Glencore's Integrated Nickel Operations, which also included nickel sulfide mines at Sudbury, Ontario Province; a smelter at Sudbury; and its Nikkelverk refinery in Norway. In 2022, 600 t of the cobalt refined at Nikkelverk was derived from concentrates produced at its Canadian nickel mines, compared with 1,100 t in 2021 (tables 7, 8; Creamer Media Reporter, 2022; Glencore plc, 2023, p. 86).

Throughout 2022, Vale S.A. and Glencore progressed mine expansion projects in Canada. Vale worked to transition its Voisey's Bay open pit mine to two underground mines, the Reid Brook and Eastern Deeps Mines, which would extend the life of its Voisey's Bay operations and increase the average annual peak production to an estimated 2,600 t/yr of cobalt. In 2021, Vale produced its first ore at the Reid Brook Mine. The mine expansion project was 81% complete by yearend 2022. Vale's refined cobalt production in Canada in 2022 included 1,169 t from ore mined from Voisey's Bay. This constituted 38% of Canada's mine output, and a 34% decrease from production in 2021. Vale also produced 367 t (304 t in 2021) of cobalt from ore mined at Sudbury, Ontario, and 143 t (35 t in 2021) of cobalt from ore mined at Thompson, Manitoba, in 2022 (Vale S.A., 2023, p. 85, 108–109).

In 2022, Glencore progressed phase II of the Sivumut Project at the Raglan Mine property in Quebec. The project included expansion of the existing Qakimajurk Mine, which was completed in 2021, and the opening of an additional underground mine. The project was expected to enable continued mining activity at Raglan through 2040. In 2022, 498 t of cobalt content was produced at Raglan (Glencore plc, undated a, b).

China.—Although only 2,000 t of cobalt was mined in China, China was the world's leading producer and consumer of refined cobalt. In 2022, China's estimated production of refined cobalt increased by 5% from that in 2021 and represented 80% of world production. Most of the production was in the form of cobalt salts and oxides (86%), with the remainder as metal and metal powder (14%). In 2022, the majority of China's consumption of refined cobalt was used to make cathode materials for rechargeable batteries (table 8; Darton Commodities Ltd., 2023, p. 23).

Numerous companies refined and (or) processed cobalt in China. In 2022, the leading producers of refined cobalt were Zhejiang Huayou Cobalt Co., Ltd. (Huayou), Shenzhen GEM High-Tech Co. Ltd. (including subsidiary Jiangsu Cobalt Nickel Metal Co. Ltd.), and Jinchuan Group Co. Ltd., listed in descending order of estimated production. Only a small portion of China's cobalt production originated from domestic sources. Domestic mine production was estimated to represent 1% of China's cobalt raw material supply, recycled scrap was estimated to represent 9%, and imported raw materials, 90%. Most of China's refinery production was from imported intermediate cobalt chemical compounds, the majority of which was sourced from Congo (Kinshasa). In 2022, China imported 124,870 t of cobalt in concentrate and intermediate materials produced from copper and nickel operations, a 31% increase from that imported in 2021. The increase in imported intermediate materials was due, in part, to increased imports of mixed hydroxide precipitate (MHP) from Indonesia as

Indonesian high-pressure acid leaching (HPAL) projects started up and increased production. China imported 2,601 t of cobalt metal, a 59% decrease from that imported in 2021 (Darton Commodities Ltd., 2023, p. 15, 23, 26, 28).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt in 2022, with estimated production increasing by 22% and representing 73% of global production. Most of the country's cobalt mine production was from copper-cobalt ores mined using industrial or mechanized methods. The rest was gathered by tens of thousands of artisanal miners handpicking cobalt-rich ores. Artisanal mining filled the role of a swing producer by increasing production during periods of supply deficits and high prices and decreasing production during periods of oversupply and low prices. Darton Commodities Ltd. (2023, p. 10) estimated that in 2022, artisanally mined cobalt composed 8% of Congo (Kinshasa)'s mine production (table 7).

Artisanal mining, particularly when not managed by local cooperatives or other types of legal entities, can be associated with negative societal and environmental effects. In 2022, efforts to formalize the artisanal mining sector and to promote ethical and sustainable cobalt production continued. Entreprise Générale du Cobalt (EGC), a subsidiary of state-owned La Générale des Carrières et des Mines SA (Gécamines), was launched in 2021 to improve the working conditions of artisanal miners by managing and controlling production, purchasing, processing, and marketing of cobalt produced by artisanal methods. EGC was not yet operational by yearend 2022 (RCS Global Group, 2022, p. 4; Baumann-Pauly, 2023, p. 5).

The majority of ores and concentrates produced in Congo (Kinshasa) were processed domestically into crude cobalt hydroxide, an intermediate material that is mostly exported to be further refined. Some concentrates also were exported.

In 2022, three companies accounted for more than one-half of Congo (Kinshasa)'s estimated cobalt mine production. Glencore was the leading producer, followed by Eurasian Resources Group S.a.r.l. (ERG) of Luxemburg (40% of which was owned by the Government of Kazakhstan), and CMOC Group Ltd. (CMOC), formerly China Molybdenum Co., Ltd. In 2022, each of these companies increased its cobalt production in Congo (Kinshasa) (CMOC Group Ltd., 2023, p. 24; Eurasian Resources Group S.a.r.l., 2023, p. 1; Glencore plc, 2023, p. 84).

Glencore had majority ownership in two copper-cobalt mining and refining operations in Congo (Kinshasa)—KCC and Mutanda, both in Lualaba Province. In 2022, KCC produced 25,500 t of cobalt in concentrates and hydroxides, a 7% increase in production from that in 2021. Mutanda produced 14,700 t of cobalt in concentrates and hydroxides, more than double production in 2021. Mutanda ramped up production after a restart in the second half of 2021. The operation had been on temporary care-and-maintenance status since 2019 (Glencore plc, 2023, p. 84, 167, 269).

ERG had majority ownership in two copper-cobalt operations in Congo (Kinshasa)—Boss Mining SAS and Metalkol Roan Tailings Reclamation. ERG's Metalkol operation recovered copper and cobalt from historic tailings deposited in the Musonoi River Valley and at the Kingamyambo Tailings Dam in Haut Katanga Province. In 2022, Metalkol's production of salable crude cobalt hydroxide increased by 9% to 22,500 t

of cobalt content, making it the second-ranked producer after KCC. In November 2022, ERG and joint-venture partner state-owned Gécamines restarted operations at Boss Mining after nearly 4 years on care-and-maintenance status. At the mine's reopening, ERG announced that it would ramp up to a full capacity of 300 metric tons per month of cobalt hydroxide by March 2023 (Eurasian Resources Group Africa, 2022; Eurasian Resources Group S.a.r.l., 2023, p. 4, 20).

CMOC had majority ownership of Tenke Fungurume Mining S.a.r.l.'s copper-cobalt mining and refining operation in Lualaba Province. In 2022, Tenke Fungurume produced crude cobalt hydroxide containing 20,286 t of cobalt, 10% more than was produced in 2021. In the third quarter of 2022, exports of production from the mine were halted owing to a dispute with state-owned Gécamines over reserves determinations and corresponding royalty payments. The dispute was ongoing at yearend 2022. The 2022 sales volume of cobalt produced from Tenke Fungurume was 12,560 t (a 26% decrease compared with that in 2021), and the 2022 yearend inventory was 11,318 t of cobalt in hydroxide (a 25% increase compared with that in 2021) (CMOC Group Ltd., 2023, p. 33, 40–41).

Finland.—Finland continued to be the second-ranked global producer of refined cobalt (table 8). Cobalt was refined at plants in Harjvalta, Kokkola, and Sotkamo.

In 2022 Terrafame Ltd. [majority owned by Finnish Minerals Group Ltd. (Government of Finland)] continued to ramp up production at its nickel-cobalt refinery that started up in 2021. The refinery was located in Sotkamo, adjacent to and vertically integrated with Terrafame's mining and processing operations. The refinery was designed to convert MSP produced at the Terrafame polymetallic mining and bioheap-leaching operation into nickel sulfate and cobalt sulfate for battery applications. The refinery had a full production capacity of 7,400 t/yr of cobalt sulfate (Terrafame Ltd., 2021, p. 3, 13–14, 23; 2023, p. 1).

Indonesia.—In 2022, Indonesia became the second-ranked cobalt-producing country or locality in the world in terms of mine output (table 7). Indonesia's cobalt mine production in 2022 was more than triple the amount produced in 2021. The sharp increase in production was due to new HPAL plants that started up in 2021 and 2022. The plants processed laterite ore to produce MHP, an intermediate product containing nickel and cobalt. MHP could be further refined to nickel sulfate and cobalt sulfate, which are key chemicals for the battery industry.

PT Halmahera Persada Lygend, a joint venture between Lygend Resources and Technology Co., Ltd. (China) and PT Trimegah Bangun Persada (Indonesia), began production of MHP in 2021 and was the first new HPAL plant operational in Indonesia. The first phase of production included two production lines with a design capacity of 37,000 t/yr of MHP containing 4,500 t/yr of cobalt. In 2022, PT Halmahera Persada Lygend produced 42,310 t of MHP containing 5,303 t of cobalt. Through the year, PT Halmahera Persada Lygend also readied a third production line with a capacity of 18,000 t/yr of MHP containing 2,250 t/yr of cobalt (PT Trimegah Bangun Persada, 2024, p. 34, 105–106).

The first full year of production at the PT Huayue Nickel Cobalt (Indonesia) [a subsidiary of Zhejiang Huayou Cobalt Co., Ltd. (China)] HPAL plant at Morowali, Central Sulawesi Province, was 2022. The plant began production in late

December 2021 and had the capacity to produce 6,000 t/yr of cobalt in MHP (Zhejiang Huayou Cobalt Co., Ltd., 2021a, b).

In September 2022, PT QMB New Energy Materials Co., Ltd. (Indonesia) [63% owned by GEM Co., Ltd. (China)] began phase 1 production of MHP at its HPAL plant located in Morowali, Central Sulawesi Province. PT QMB's phase 1 design capacity was an estimated 2,800 t/yr of cobalt content and 30,000 t/yr of nickel content, and planned full capacity was 7,000 t/yr of cobalt and 73,000 t/yr of nickel in MHP (GEM Co., Ltd., 2023, p. 34–35; PT QMB New Energy Materials Co., Ltd., undated a, b).

Madagascar.—The Ambatovy joint venture [Sumitomo Corp. (Japan) and Korea Mine Rehabilitation and Mineral Resources Corp. (KOMIR) (formerly Korea Resources Corp.)] was Madagascar's sole nickel-cobalt mining, processing, and refining operation. Operations restarted in the quarter ending March 31, 2021, and production continued throughout the full year 2022. The operation had been placed on care-and-maintenance status in late March 2020 in response to COVID-19 pandemic-related lockdown restrictions. In 2022, refined cobalt production, in the form of metal briquettes, increased by 42% from that in 2021 (tables 7, 8; Ambatovy, 2022, p. 12, 20; 2023, p. 14).

Zambia.—Jubilee Metals Group Plc (United Kingdom) progressed multiple aspects of its plan to produce refined copper and cobalt from tailings generated during previous mining operations and run-of-mine concentrates. In 2022, Jubilee completed construction and began operations at its beneficiation plant in Ndola and began production of cobalt hydroxide at its polymetallic Sable Refinery near Kabwe. The refinery had a planned capacity of 1,500 t/yr of cobalt in hydroxide with flexibility to switch between copper and cobalt production depending on market conditions. The Ndola and Kabwe facilities made up one of two planned operation centers in Zambia, each composed of tailings stockpiles, beneficiation plants, and a refinery. The second operation center was in the design phase at yearend 2022 and would incorporate refining capacity at the Mopani Copper Mines Plc (a subsidiary of ZCCM–IH) refinery in Kitwe (Jubilee Metals Group Plc, 2022, p. 12, 22; 2023, p. 2, 7–8).

Outlook

Several industry analysts forecast that global cobalt mine and intermediate production will increase significantly in the coming years, particularly from mines and processing plants in Congo (Kinshasa) and Indonesia. Supply of refined cobalt is expected to keep pace with the availability of mined and intermediate feed supplies. Cobalt from recycling end-of-life lithium-ion batteries is expected to increase over time. Most analysts forecast that increased supply will maintain an oversupplied market in 2023, potentially lasting into 2025, when increasing demand from the EV industry will result in a deficit between cobalt supply and consumption. Regardless of the long-term trends in noncobalt battery chemistries, cobalt demand for lithium-ion batteries is expected to continue to increase into the 2030s (Argus Media Group, 2022, p. 1; Go, 2022; Kinch, 2022; Ouerghi and Ghilotti, 2022; Project Blue Group Ltd., The, 2022b, p. 6; Fastmarkets team and others, 2023).

References Cited

- Ambatovy, 2022, Sustainability report 2021: Antananarivo, Madagascar, Ambatovy, 82 p. (Accessed December 19, 2023, at <https://ambatovy.com/en/wp-content/uploads/2022/10/Ambatovy-Sustainability-Report-2021-EN.pdf>.)
- Ambatovy, 2023, Sustainability report 2022: Antananarivo, Madagascar, Ambatovy, 85 p. (Accessed May 3, 2024, at <https://ambatovy.com/en/wp-content/uploads/2023/09/Ambatovy-Sustainability-Report-2022-EN.pdf>.)
- Argus Media Group, 2022, Viewpoint—Cobalt supply to outpace demand: Argus Battery Materials, no. 22–249, December 28, 11 p. (Accessed April 4, 2023, via <https://direct.argusmedia.com/>.)
- Ascend Elements Inc., 2022, Ascend Elements awarded \$480M in grants from U.S. Department of Energy to manufacture sustainable battery cathode active materials: Westborough, MA, Ascend Elements Inc. press release, October 19. (Accessed April 19, 2024, at <https://ascendelements.com/ascend-elements-awarded-480m-in-grants-from-u-s-department-of-energy-to-manufacture-sustainable-battery-cathode-active-materials/>.)
- Baumann-Pauly, Dorothee, 2023, Cobalt mining in the Democratic Republic of Congo—Addressing root causes of human rights abuses: New York, NY, NYU Stern Center for Business and Human Rights, 14 p. (Accessed May 2, 2024, at <https://gcbhr.org/backoffice/resources/cobalt-mining-drcroot-causes.pdf>.)
- BHP Group Ltd., 2023, Annual report 2022: Melbourne, Victoria, Australia, BHP Group Ltd., 244 p. (Accessed May 9, 2024, at https://www.bhp.com/-/media/documents/investors/annual-reports/2022/220906_bhpannualreport2022.pdf.)
- Cirba Solutions, 2022a, Cirba Solutions awarded \$75M in DOE grant funding: Charlotte, NC, Cirba Solutions press release, October 19. (Accessed April 19, 2024, at <https://www.cirbasolutions.com/cirba-solutions-awarded-75m-in-doe-grant-funding/>.)
- Cirba Solutions, 2022b, Cirba Solutions receives additional \$7+ million from the DOE: Charlotte, NC, Cirba Solutions press release, November 29. (Accessed April 19, 2024, at <https://www.cirbasolutions.com/cirba-solutions-receives-additional-7-million-from-the-doe/>.)
- CMOC Group Ltd., 2023, 2022 annual report: Luoyang City, China, CMOC Group Ltd., 372 p. (Accessed May 1, 2024, at <https://www.l.hkxnews.hk/listedco/listconews/sehk/2023/0428/2023042804425.pdf>.)
- Cobalt Institute, 2023, Cobalt market report 2022: Guildford, United Kingdom, Cobalt Institute, May, 43 p. (Accessed April 19, 2024, at https://www.cobaltinstitute.org/wp-content/uploads/2023/05/Cobalt-Market-Report-2022_final.pdf.)
- Creamer Media Reporter, 2022, New collective agreement ends 100-day Raglan strike: Mining Weekly [Johannesburg, South Africa], September 9. (Accessed September 9, 2022, via <https://www.miningweekly.com/>.)
- Darton Commodities Ltd., 2023, Cobalt market review 2023: Guildford, United Kingdom, Darton Commodities Ltd., 67 p. (Accessed March 5, 2024, via <https://www.dartoncommodities.co.uk/>.)
- Desai, Pratima, 2023, Cobalt supplies to swamp market, pressure prices further: Thomson Reuters, March 7. (Accessed April 19, 2024, at <https://www.reuters.com/markets/commodities/cobalt-supplies-swamp-market-pressure-prices-further-2023-03-07/>.)
- Eurasian Resources Group Africa, 2022, ERG and Gécamines restart operations at Boss Mining in the DRC: Johannesburg, South Africa, Eurasian Resources Group Africa news release, December 6, 2 p. (Accessed May 1, 2024, at <https://www.ergafrica.com/wp-content/uploads/Media-Release-ERG-and-Gecamines-restart-operations-at-Boss-Mining-in-the-DRC.pdf>.)
- Eurasian Resources Group S.a.r.l., 2023, Resilient, agile and delivering societal value—Sustainable development report 2022: Luxembourg, Luxembourg, Eurasian Resources Group S.a.r.l., 92 p. (Accessed May 2, 2024, at [https://eurasianresources.lu/uploads/1/files/ERG%20SDR%202022%20\(ENG\).pdf](https://eurasianresources.lu/uploads/1/files/ERG%20SDR%202022%20(ENG).pdf).)
- Fastmarkets team, Yang, Justin, and Cook, Alexander, 2023, Cobalt ends year on volatile note; some long-term negotiations drag on—2023 preview: Fastmarkets [London, United Kingdom], January 6 (Accessed June 5, 2024, at <https://www.fastmarkets.com/insights/cobalt-ends-year-on-volatile-note/>.)
- GEM Co., Ltd., 2023, 2022 annual report: Shenzhen, China, GEM Co., Ltd., April 27, 409 p. (Accessed May 2, 2024, at <https://en.gem.com.cn/uploadfiles/2023/04/20230429002359523.pdf>.)
- Glencore plc, 2023, Annual report 2022: Baar, Switzerland, Glencore plc, March 22, 284 p. (Accessed May 2, 2024, at <https://www.glencore.com/rest/api/v1/documents/ded10fa92974aa388a43aa9f86f483e9/GLEN-2022-Annual-Report.pdf>.)
- Glencore plc, [undated]a, Raglan Mine—Our mining activity: Baar, Switzerland, Glencore plc. (Accessed April 15, 2024, at <https://www.glencore.ca/en/raglan/what-we-do/our-mining-activity>.)
- Glencore plc, [undated]b, Sivumut project: Baar, Switzerland, Glencore plc. (Accessed April 12, 2024, at <https://www.glencore.ca/en/raglan/what-we-do/sivumut-project>.)
- Go, R.J., 2022, EV mandates in EU, California may run into short-term metal constraints: S&P Global Market Intelligence, November 4. (Accessed November 4, 2022, via <https://www.spglobal.com/>.)
- Jervois Global Ltd., 2022a, Annual information form for the fiscal year ended December 31, 2021: Cremorne, Victoria, Australia, Jervois Global Ltd., 87 p. (Accessed April 22, 2024, <https://jervoisglobal.com/wp-content/uploads/2022/04/JRV-AIF-Dec-31-2021-final.pdf>.)
- Jervois Global Ltd., 2022b, Jervois commences commissioning at Idaho Cobalt Operations in the U.S.: Cremorne, Victoria, Australia, Jervois Global Ltd. ASX release, October 10, 5 p. (Accessed April 22, 2024, at <https://wsecure.weblink.com.au/pdf/JRV/02579842.pdf>.)
- Jervois Global Ltd., 2023, Annual report to shareholders 2022: Cremorne, Victoria, Australia, Jervois Global Ltd., 163 p. (Accessed June 20, 2023, at <https://jervoisglobal.com/wp-content/uploads/2023/03/Jervois-Global-Annual-Report-2022-website.pdf>.)
- Jubilee Metals Group Plc, 2022, Integrated annual report 2022: London, United Kingdom, Jubilee Metals Group Plc, 158 p. (Accessed August 30, 2023, at <https://jubileemetalsgroup.com/wp-content/uploads/2024/02/Annual-Report-for-the-year-ended-30-June-2022.pdf>.)
- Jubilee Metals Group Plc, 2023, Unaudited condensed half-yearly financial report for the six months to 31 December 2022: London, United Kingdom, Jubilee Metals Group Plc news release, March 20, 21 p. (Accessed May 7, 2024, at <https://jubileemetalsgroup.com/wp-content/uploads/2024/02/Unaudited-Interim-Results-for-six-months-to-31-December-2022.pdf>.)
- Kinch, Diana, 2022, Project Blue expects ‘peak cobalt’ demand in 2030s on battery chemistry changes: Platts Metals Daily, October 31. (Accessed November 19, 2022, via <https://www.spglobal.com/commodityinsights/en/products-services/metals/metals-daily>.)
- Lundin Mining Corp., 2023, Annual information form for the year ended December 31, 2022: Toronto, Ontario, Canada, Lundin Mining Corp., February 22, 132 p. (Accessed April 22, 2024, at https://lundinmining.com/site/assets/files/8444/221231_-_lundin_mining_aif.pdf.)
- Mincor Resources NL, 2020, Mincor nickel operations definitive feasibility study results: Perth, Western Australia, Australia, Mincor Resources NL news release, March 25, 42 p. (Accessed March 19, 2024, at https://minedocs.com/20/MNO_FS_03252020.pdf.)
- Mincor Resources NL, 2023, Annual report 2022: Perth, Western Australia, Australia, Mincor Resources NL, 94 p. (Accessed May 9, 2024, at https://www.annualreports.com/HostedData/AnnualReports/PDF/ASX_MCR_2022.pdf.)
- Nth Cycle, 2022, Nth Cycle awarded \$2.15 million U.S. Department of Energy grant: Beverly, MA, Nth Cycle press release, December 20. (Accessed April 19, 2024, at <https://nthcycle.com/news/nth-cycle-awarded-2-15-million-u-s-department-of-energy-grant/>.)
- Ouerghi, Dalila, and Ghilotti, Davide, 2022, Energy transition goals pose challenges and opportunities for battery recycling: Fastmarkets [London, United Kingdom], March 30. (Accessed July 25, 2022, via <https://www.fastmarkets.com/>.)
- PolyMet Mining Corp., 2022, PolyMet strikes 50–50 joint venture agreement with Teck Resources—Joint venture to develop NorthMet, further study Mesaba opportunity: St. Paul, MN, PolyMet Mining Corp. news release, July 20, 11 p. (Accessed April 22, 2024, at <https://www.sedarplus.ca/csa-party/records/document.html?id=e7aab2de25a3029b7115302fb7163e8619245960bb0135e85ee1b4a482270084>.)
- PolyMet Mining Corp., 2023, Annual information form for the year ended December 31, 2022: St. Paul, MN, PolyMet Mining Corp., March 23, 71 p. (Accessed April 22, 2024, at <https://www.sedarplus.ca/csa-party/records/document.html?id=cefaf1e22ca8adf33aac3fbc3309e91e247458bf4cba6d45ca14321dbdfdd1f>.)
- Princeton NuEnergy, 2022, Princeton NuEnergy (PNE) awarded \$12M grant from U.S. Department of Energy (DOE): PRNewswire, November 18. (Accessed April 19, 2024, at <https://www.prnewswire.com/news-releases/princeton-nuenergy-pne-awarded-12m-grant-from-us-department-of-energy-doe-301682328.html>.)
- Project Blue Grp. Ltd., The, 2022a, Cobalt 101: London, United Kingdom, The Project Blue Grp. Ltd., 17 p. (Accessed August 12, 2024, via <https://www.projectblue.com/>.)
- Project Blue Grp. Ltd., The, 2022b, Cobalt 203—October 2022: London, United Kingdom, The Project Blue Grp. Ltd., July, 15 p. (Accessed August 12, 2024, via <https://www.projectblue.com/>.)

- PT QMB New Energy Materials Co., Ltd., [undated]a, High pressure acid leaching technology (HPAL): Jakarta, Indonesia, PT QMB New Energy Materials Co., Ltd. (Accessed May 2, 2024, at <http://www.qmbworld.com/HAPLTechnology/index.aspx>.)
- PT QMB New Energy Materials Co., Ltd., [undated]b, Introduction to QMB: Jakarta, Indonesia, PT QMB New Energy Materials Co., Ltd. (Accessed May 2, 2024, at <http://www.qmbworld.com/gsj/index.aspx>.)
- PT Trimegah Bangun Persada, 2024, 2023 annual report: Jakarta, Indonesia, Harita Nickel, 458 p. (Accessed May 2, 2024, at https://tbpnickel.com/files/pdf_assets/2023%20Annual%20Report.pdf.)
- RCS Global Group, 2022, Cobalt supply chain mapping report: London, United Kingdom, RCS Global Group, 33 p. (Accessed May 2, 2024, via <https://www.elevatelimited.com/wp-content/uploads/2022/08/RCS-GTP-Cobalt-Supply-Chain-Mapping-Report-May-2022.pdf>.)
- Stillwater Mining Co., 2017, Form 10-K—2016: U.S. Securities and Exchange Commission, February 16, 108 p. (Accessed May 9, 2023, at <https://www.sec.gov/Archives/edgar/data/931948/000093194817000012/swc-12312016x10k.htm>.)
- Talon Metals Corp., 2022a, November 2022 national instrument 43-101 technical report of the Tamarack North Project—Tamarack, Minnesota: Tamarack, MN, Talon Metals Corp., November 2. (Accessed August 12, 2024, at https://talonmetals.com/wp-content/uploads/2022/11/Final_NI43101_Report_Talon_TamarackN_20221102.pdf.)
- Talon Metals Corp., 2022b, Talon Metals battery minerals processing facility selected by U.S. Department of Energy for \$114 million in Bipartisan Infrastructure Law funding: Tamarack, MN, Talon Metals Corp. press release, October 19. (Accessed April 19, 2024, at <https://talonmetals.com/wp-content/uploads/2022/10/Bipartisan-Infrastructure-Law-DOE-Talon-Funding-FINAL.pdf>.)
- Terrafame Ltd., 2021, Creating responsible battery value chain—Sustainability review June 2021: Tuhkakyta, Finland, Terrafame Ltd., June, 34 p. (Accessed May 7, 2024, at <https://issuu.com/terrafame/docs/terrafame-sustainable-review-june-2021>.)
- Terrafame Ltd., 2023, Terrafame's net sales increased significantly in 2022—Operating result above EUR 90 million: Tuhkakyta, Finland, Terrafame Ltd. news release, March 3, 11 p. (Accessed May 7, 2024, at <https://www.terrafame.com/media/mediamateriaali/raportointi/osavuositatsaukset/2022/q4/terrafames-net-sales-increased-significantly-in-2022.pdf>.)
- U.S. Department of Defense, 2022a, Defense Production Act Title III Presidential determination for critical materials in large-capacity batteries: Washington, DC, U.S. Department of Defense press release, April 5. (Accessed April 19, 2024, at <https://www.defense.gov/News/Releases/Release/Article/2989973/defense-production-act-title-iii-presidential-determination-for-critical-materi/>.)
- U.S. Department of Defense, 2022b, State of competition within the defense industrial base: Washington, DC, U.S. Department of Defense, 28 p. (Accessed June 27, 2023, at <https://media.defense.gov/2022/Feb/15/2002939087/-1/-1/1/STATE-OF-COMPETITION-WITHIN-THE-DEFENSE-INDUSTRIAL-BASE.PDF>.)
- U.S. Department of Energy, 2022a, Bipartisan Infrastructure Law battery materials processing and battery manufacturing & recycling funding opportunity announcement (DE-FOA-0002678) selections: Washington, DC, U.S. Department of Energy, 22 p. (Accessed August 12, 2024, at <https://www.energy.gov/sites/default/files/2022-11/DOE%20BIL%20Battery%20FOA-2678%20Selectee%20Fact%20Sheets.pdf>.)
- U.S. Department of Energy, 2022b, Bipartisan Infrastructure Law electric drive vehicle battery recycling and second life applications funding opportunity announcement (DE-FOA-0002680) selections: Washington, DC, U.S. Department of Energy, 22 p. (Accessed August 12, 2024, at <https://www.energy.gov/sites/default/files/2022-11/Recycling%20and%20Second-Use%20Selections%20Factsheets%2011-16.pdf>.)
- U.S. Department of the Interior, Office of the Secretary, 2018, Final list of critical minerals 2018: Federal Register, v. 83, no. 97, May 18, p. 23295–23296. (Accessed August 12, 2024, at <https://www.govinfo.gov/content/pkg/FR-2018-05-18/pdf/2018-10667.pdf>.)
- U.S. Department of Labor, 2022a, 2022 list of goods produced by child labor or forced labor: Washington, DC, U.S. Department of Labor, 99 p. (Accessed April 19, 2024, at https://www.dol.gov/sites/dolgov/files/ILAB/child_labor_reports/tda2021/2022-TVPRA-List-of-Goods-v3.pdf.)
- U.S. Department of Labor, 2022b, Final evaluation combatting child labor in the Democratic Republic of the Congo's cobalt industry (COTECCO): Washington, DC, U.S. Department of Labor, 88 p. (Accessed June 27, 2023, at https://www.dol.gov/sites/dolgov/files/ILAB/evaluation_type/final_evaluation/DRC-COTECCO-Final-Evaluation-Report-NonPIL.pdf.)
- U.S. Geological Survey, 2022, 2022 final list of critical minerals: Federal Register, v. 87, no. 37, February 24, p. 10381–10382. (Accessed June 23, 2023, at <https://www.govinfo.gov/content/pkg/FR-2022-02-24/pdf/2022-04027.pdf>.)
- U.S. Strategic Metals, LLC, 2022, U.S. Strategic Metals announces wholly domestic production of critical minerals for electric vehicle batteries: St. Louis, MO, U.S. Strategic Metals, LLC press release, September 14. (Accessed April 22, 2024, at <https://www.usstrategicmetals.com/news/us-strategic-metals-announces-wholly-domestic-production-of-critical-minerals-for-electric-vehicle-batteries>.)
- Vale S.A., 2023, Form 20-F—For the fiscal year ended December 31, 2022: U.S. Securities and Exchange Commission, April 12, 213 p. (Accessed June 10, 2024, at https://www.sec.gov/Archives/edgar/data/917851/000129281423001516/valeform20f_2022.htm.)
- White House, The, 2023, A guidebook to the Inflation Reduction Act's investments in clean energy: Washington, DC, The White House, 183 p. (Accessed June 23, 2023, at <https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf>.)
- Yu, Alice, 2023, Lithium and cobalt CBS March 2023—Lithium prices slide, cobalt prices steady: S&P Global Market Intelligence, April 5. (Accessed April 19, 2024, at <https://www.spglobal.com/marketintelligence/en/news-insights/research/lithium-and-cobalt-cbs-march-2023-lithium-prices-slide-cobalt-prices-steady>.)
- Zhejiang Huayou Cobalt Co., Ltd., 2021a, Indonesia Huayue, the first batch of qualified products!: Zhejiang Province, China, Zhejiang Huayou Cobalt Co., Ltd. news release, December 24. (Accessed December 19, 2023, at <https://en.huayou.com/news/609.html>.)
- Zhejiang Huayou Cobalt Co., Ltd., 2021b, Luhut Binsar Pandjaitan, Minister of Ministry of Maritime and Investment Coordination in Indonesia inspects the Huayue nickel and cobalt project: Zhejiang Province, China, Zhejiang Huayou Cobalt Co., Ltd. news release, June 25. (Accessed December 19, 2023, at <https://en.huayou.com/news/565.html>.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Cobalt. Ch. in *Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply*, Professional Paper 1802, 2017.
- Cobalt. Ch. in *Mineral Commodity Summaries*, annual.
- Cobalt. *International Strategic Minerals Inventory Summary Report*, Circular 930–F, 1987.
- Cobalt. *Mineral Industry Surveys*, monthly.
- Cobalt (Co). Ch. in *Metal Prices in the United States Through 2010*, Scientific Investigations Report 2012–5188, 2013.
- Cobalt Deposits in the United States. Data release, 2018.
- Cobalt—For Strength and Color. Fact Sheet 2011–3081, 2011.
- Cobalt Recycling in the United States in 1998. Ch. in *Flow Studies for Recycling Metal Commodities in the United States*, Circular 1196–A–M, 2004.
- Historical Statistics for Mineral and Material Commodities in the United States*. Data Series 140.

Other

- Cobalt. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.
- Cobalt. *Mineral Profile*, British Geological Survey, 2009.
- Cobalt Institute (formerly known as the Cobalt Development Institute).
- Defense Logistics Agency Strategic Materials.
- Materials Flow of Cobalt in the United States*, The. U.S. Bureau of Mines Information Circular 9350, 1993.

TABLE 1
SALIENT COBALT STATISTICS¹

(Metric tons, cobalt content, unless otherwise specified)

	2018	2019	2020	2021	2022	
United States:						
Mine production ^c	480	500	600	650	500	
Consumption:²						
Estimated	9,290	9,050	7,260	7,270	7,650	
Apparent ³	7,680	12,500	8,480	6,650	7,060	
Imports for consumption	11,900	13,900	9,740	9,790 ^r	10,500	
Exports	6,980	4,080	3,430	4,930	5,360	
Stocks, December 31:						
Industry ^{c,4}	1,060	1,090	952	1,010	947	
London Metal Exchange Ltd. (LME), U.S. warehouses	130	102	82	50	34	
Price, metal:						
U.S. spot ⁵	dollars per pound	37.43	16.95	15.70	24.21	30.78
LME, cash ⁶	do.	32.94	14.88	14.21	23.17	28.83
World:						
Production:⁷						
Mine	148,000 ^r	153,000 ^r	147,000	162,000 ^r	197,000	
Refinery	126,000	139,000	146,000 ^r	171,000 ^r	174,000	
Stocks, December 31, LME ⁸	863	685	451	256	165	

^cEstimated. ^rRevised. do. Ditto.

¹Table includes data available through May 1, 2024. Data are rounded to no more than three significant digits, except prices.

²Includes reported data and U.S. Geological Survey estimates.

³For 2018–2021, defined as imports minus exports plus adjustments for Government and industry stock changes plus secondary production, as estimated from consumption of purchased scrap. Beginning in 2022, Government stocks no longer included.

⁴Stocks held by cobalt processors and consumers.

⁵Annual average U.S. spot price for minimum 99.8% cobalt cathode. Source: S&P Global Platts Metals Week.

⁶Annual average mean of the cash buyer price and cash seller price, cobalt briquettes, cathode, ingot, or rounds, converted from dollars per metric ton. Effective January 19, 2018, the LME increased the minimum grade of cobalt metal to be delivered under the cobalt contract from 99.3% cobalt to 99.8% cobalt.

⁷May include estimated data.

⁸Stocks held in Asia, Europe, and the United States.

TABLE 2
U.S. ESTIMATED CONSUMPTION AND STOCKS OF COBALT^{1,2}

(Metric tons, cobalt content)

	2021	2022
Consumption by end use:		
Cemented carbides ³	708	715
Chemical and ceramic uses	2,170	2,120
Steels and other alloys, excludes superalloys ⁴	1,180	1,180
Superalloys	3,220	3,640
Total	7,270	7,650
Consumption by form:		
Chemical compounds, organic and inorganic ⁵	2,150	2,110
Metal	3,320	3,710
Purchased scrap	1,800	1,830
Total	7,270	7,650
Stocks, December 31: ⁶		
Chemical compounds, organic and inorganic ⁵	388	378
Metal	W	W
Purchased scrap	W	W
Total	1,010	947

W Withheld to avoid disclosing company proprietary data; included in "Total."

¹Table includes data available through May 1, 2024. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes reported data and U.S. Geological Survey estimates.

³Includes cast carbide dies or parts, cemented and sintered carbides, and diamond tool matrices.

⁴Includes magnetic alloys, nonferrous alloys, wear- and corrosion-resistant alloys, welding materials, and other metallic uses not listed.

⁵Includes oxides.

⁶Stocks held by cobalt processors and consumers.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM¹

Form	HTS ² codes	2021			2022		
		Gross weight (metric tons)	Cobalt content ³ (metric tons)	Value ⁴ (thousands)	Gross weight (metric tons)	Cobalt content ³ (metric tons)	Value ⁴ (thousands)
Metal ⁵	8105.20.6000 and 8105.20.9000	7,240 ^r	7,240 ^r	\$324,000 ^r	7,200	7,200	\$458,000
Oxides and hydroxides	2822.00.0000	2,190 ^r	1,570 ^r	73,900 ^r	1,920	1,380	89,100
Other:							
Acetates	2915.29.3000	769	185	10,700	1,360	327	11,500
Carbonates	2836.99.1000	584	269	13,500	576	265	14,400
Chlorides	2827.39.6000	115	29	1,230	150	38	1,760
Sulfates	2833.29.1000	1,850	500	15,000	4,810	1,300	22,500
Total		12,700 ^r	9,790 ^r	439,000	16,000	10,500	597,000

^rRevised.

¹Table includes data available through September 18, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

³Estimated from gross weight using the following percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; carbonates, 46%; chlorides, 25%; and sulfates, 27%.

⁴Customs value.

⁵Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY OR LOCALITY¹

Country or locality	Metal ²			Oxides and hydroxides ³			Other forms ⁴			Total		
	Quantity (metric tons)		Value ⁶ (thousands)	Quantity (metric tons)		Value ⁶ (thousands)	Quantity (metric tons)		Value ⁶ (thousands)	Quantity (metric tons)		Value ⁶ (thousands)
	Gross weight	Cobalt content ⁵		Gross weight	Cobalt content ⁵		Gross weight	Cobalt content ⁵		Gross weight	Cobalt content ⁵	
2021:												
Australia	191	191	9,770	17	12	446	--	--	--	208	203	10,200
Belgium	25	25	1,410	508	366	18,300	144	41	1,770	677	431	21,500
Brazil	--	--	--	42	30	1,340	528	158	4,030	571	188	5,370
Canada	904	904	38,200	--	--	--	3	1	61	907	905	38,300
China	29	29	771	27 ^r	19 ^r	749 ^r	102	28	916	158 ^r	76 ^r	2,440 ^r
Finland	510	510	24,900	774	557	25,100	1,460	471	20,300	2,740	1,540	70,300
Germany	103	103	6,190	1	1	43	31	9	376	135	113	6,610
Japan	1,120	1,120	44,400	--	--	--	22	5	114	1,140	1,120	44,500
Korea, Republic of	(7)	(7)	30	42	30	1,270	--	--	--	43	31	1,300
Madagascar	120	120	6,110	--	--	--	--	--	--	120	120	6,110
Mexico	60	60	2,120	4	3	82	19	5	280	83	68	2,480
Morocco	142	142	5,320	--	--	--	--	--	--	142	142	5,320
Norway	3,150	3,150	147,000	--	--	--	--	--	--	3,150	3,150	147,000
Russia	772 ^r	772 ^r	32,600 ^r	--	--	--	(7)	(7)	4	772 ^r	772 ^r	32,600 ^r
South Africa	47	47	1,620	--	--	--	--	--	--	47	47	1,620
Taiwan	--	--	--	153	110	5,740	620	157	6,410	774	267	12,200
United Kingdom	52	52	3,380	608	438	20,500	380	104	5,950	1,040	595	29,900
Other	12	12	518	9	7	293	10	3	183	32	22	994
Total	7,240 ^r	7,240 ^r	324,000 ^r	2,190 ^r	1,570 ^r	73,900 ^r	3,320	982	40,400	12,700 ^r	9,790 ^r	439,000
2022:												
Australia	145	145	8,880	11	8	320	--	--	--	156	153	9,200
Belgium	64	64	3,750	280	202	15,300	21	5	413	365	271	19,500
Brazil	--	--	--	4	3	157	823	245	6,590	828	248	6,750
Canada	1,390	1,390	84,000	--	--	--	1	(7)	17	1,390	1,390	84,000
China	81	81	2,780	52	38	1,460	200	55	1,220	333	174	5,460
Finland	318	318	25,800	933	672	42,400	3,670	1,060	25,400	4,920	2,050	93,600
Germany	148	148	13,000	9	7	146	45	12	376	202	167	13,500
Hong Kong	--	--	--	--	--	--	181	49	696	181	49	696
India	--	--	--	--	--	--	103	28	467	103	28	467
Japan	1,260	1,260	80,200	(7)	(7)	3	--	--	--	1,260	1,260	80,200
Korea, Republic of	(7)	(7)	20	94	67	1,270	--	--	--	94	68	1,290
Madagascar	252	252	19,000	--	--	--	--	--	--	252	252	19,000
Mexico	--	--	--	3	2	128	102	28	393	105	30	521
Morocco	195	195	12,200	--	--	--	--	--	--	195	195	12,200
Netherlands	--	--	--	16	11	550	23	6	118	39	17	668
Norway	2,580	2,580	171,000	--	--	--	--	--	--	2,580	2,580	171,000
Russia	455	455	24,300	--	--	--	--	--	--	455	455	24,300
South Africa	167	167	2,050	--	--	--	211	57	812	378	224	2,860
Taiwan	--	--	--	101	73	4,980	754	187	7,820	856	260	12,800
Turkey	32	32	1,030	--	--	--	--	--	--	32	32	1,030
United Kingdom	56	56	4,690	402	289	21,900	742	191	5,720	1,200	536	32,300
Zambia	54	54	4,200	--	--	--	--	--	--	54	54	4,200
Other	8	8	633	13	9	482	20	6	223	41	24	1,340
Total	7,200	7,200	458,000	1,920	1,380	89,100	6,900	1,930	50,200	16,000	10,500	597,000

^rRevised. -- Zero.

¹Table includes data available through September 18, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.

²Unwrought cobalt, excluding alloys and waste and scrap; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy. Harmonized Tariff Schedule of the United States (HTS) codes 8105.20.6000 and 8105.20.9000.

³HTS code 2822.00.0000.

⁴Cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates under HTS codes 2827.39.6000, 2833.29.1000, 2836.99.1000, and 2915.29.3000.

⁵Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; carbonates, 46%; sulfates, 27%; chlorides, 25%; and acetates, 24%.

⁶Customs value.

⁷Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS OF COBALT, BY COUNTRY OR LOCALITY^{1,2}

Country or locality	Metal ³		Oxides and hydroxides ⁴		Acetates ⁵		Chlorides ⁶		Total	
	Gross weight (metric tons)	Value ⁷ (thousands)	Gross weight (metric tons)	Value ⁷ (thousands)	Gross weight (metric tons)	Value ⁷ (thousands)	Gross weight (metric tons)	Value ⁷ (thousands)	Cobalt content ⁸ (metric tons)	Value ⁷ (thousands)
2021:	4,900	\$139,000	43	\$1,060	8	\$105	1	\$28	4,930	\$140,000
2022:										
Argentina	7	562	--	--	--	--	--	--	7	562
Australia	56	1,380	(9)	5	--	--	--	--	56	1,390
Belgium	36	1,510	--	--	--	--	--	--	36	1,510
Brazil	41	3,920	1	25	--	--	--	--	42	3,940
Canada	1,920	23,800	6	228	--	--	--	--	1,930	24,100
China	161	10,500	8	339	--	--	(9)	6	167	10,800
Colombia	5	64	(9)	25	--	--	--	--	6	89
France	334	11,600	(9)	5	--	--	--	--	334	11,600
Germany	456	22,900	12	468	(9)	5	--	--	465	23,400
India	101	4,190	(9)	12	--	--	--	--	101	4,200
Indonesia	5	294	--	--	--	--	--	--	5	294
Ireland	925	26,800	--	--	--	--	--	--	925	26,800
Italy	23	2,460	--	--	--	--	--	--	23	2,460
Japan	96	8,010	(9)	14	--	--	--	--	97	8,020
Korea, Republic of	88	6,530	(9)	5	--	--	--	--	88	6,540
Mexico	32	3,300	2	118	--	--	(9)	4	34	3,420
Netherlands	30	1,410	7	271	--	--	--	--	35	1,680
Singapore	52	4,930	--	--	--	--	--	--	52	4,930
Switzerland	23	1,270	--	--	--	--	--	--	23	1,270
Taiwan	51	2,110	(9)	3	--	--	--	--	51	2,120
Tunisia	104	2,670	--	--	--	--	--	--	104	2,670
Turkey	37	2,110	--	--	--	--	--	--	37	2,110
United Arab Emirates	12	900	--	--	--	--	--	--	12	900
United Kingdom	705	22,100	1	23	--	--	--	--	706	22,100
Other	24	3,280	6	228	--	--	--	--	28	3,500
Total	5,330	169,000	43	1,770	(9)	5	1	11	5,360	170,000

-- Zero.

¹Table includes data available through September 18, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.

²In addition to the materials listed, the United States exported cobalt ores and concentrates and wrought cobalt and cobalt articles.

³Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy exported under Schedule B of the United States numbers 8105.20.0000 and 8105.30.0000.

⁴Schedule B number 2822.00.0000.

⁵Schedule B number 2915.29.3000.

⁶Schedule B number 2827.39.6000.

⁷Free alongside ship value.

⁸Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; and chlorides, 25%.

⁹Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2022^{1,2}

(Metric tons, cobalt content)

Country or locality	Capacity
Australia	6,900 ^e
Belgium	3,000 ^e
Brazil	2,000
Canada	8,120
China	166,000
Congo (Kinshasa)	6,050 ^e
Finland ³	18,000 ^e
France	600
India	1,000 ^e
Japan	5,500 ^e
Korea, Republic of	1,200
Madagascar	5,600
Mexico	1,700
Morocco	2,800
Norway	5,200
Russia	3,000
South Africa	3,000 ^e
Uganda	720
United Kingdom	1,800
Zambia	9,600
Total	252,000

^eEstimated.

¹Table includes data available through September 18, 2023. Data are rounded to no more than three significant digits; may not add to total shown.

²Includes standby capacity. Refinery products include cobalt metal, metal powders, oxides, and (or) salts.

³Increased to include capacity for Terrafame Ltd.'s refinery, which began production in 2022.

TABLE 7
COBALT: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY^{1,2}

(Metric tons, cobalt content)

Country or locality ³	2018	2019	2020	2021	2022
Australia ⁴	4,878	5,741	5,626	5,232 ^r	5,786
Brazil	-- ^e	30 ^e	160 ^e	266	291
Canada ⁵	3,279	4,365	4,328 ^r	3,964 ^r	3,063
China	2,241 ^r	1,742 ^r	2,000 ^{r,e}	2,000 ^{r,e}	2,000 ^e
Congo (Kinshasa) ⁶	104,000	107,000	100,000 ^r	118,000 ^r	144,000
Cuba ^{6,7}	3,600	3,600 ^r	3,800 ^r	3,800 ^r	3,700
Finland	1,377	1,454	1,559	1,084	1,235
Indonesia ^{e,8}	1,200	1,100	1,100	2,700 ^r	9,600
Madagascar ^{e,9}	3,300	3,400	970	2,800	3,500
Mexico ^e	1,400	1,100	1,000	1,100	600
Morocco ^{e,10}	2,300	2,200 ^r	1,900 ^r	1,600 ^r	1,700
New Caledonia ^{e,11}	2,100	1,700	2,200	1,100	2,000
Papua New Guinea ¹²	3,275	2,911	2,941	2,953	2,987
Philippines ^{e,13}	3,600	4,300	4,100	3,600	3,900
Russia ¹⁴	8,700	9,400	9,700	8,000	9,200 ^e
South Africa	1,007 ^r	1,027 ^r	897 ^r	355 ^r	250
Turkey ¹⁵	259	610 ^{r,e}	2,550 ^{r,e}	2,700 ^{r,e}	2,100 ^e
United States ^{e,14}	480	500	600	650	500
Zambia	835	878 ^r	316	247	251
Zimbabwe	402	402	956	345 ^r	241
Total	148,000 ^r	153,000 ^r	147,000	162,000 ^r	197,000

^eEstimated. ^rRevised. -- Zero.

¹Table includes data available through November 13, 2023. All data are reported unless otherwise noted; totals may include estimated data. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Figures represent recoverable cobalt content from ores, concentrates, or intermediate products from cobalt, copper, nickel, platinum, or zinc operations.

³Other copper-, iron (pyrite)-, nickel-, platinum-, or zinc-producing countries and (or) localities also may have produced ores containing cobalt as a byproduct component, but recovery was small or zero.

⁴Cobalt content of lateritic nickel ore and nickel concentrate reported by the government of Western Australia.

⁵Recoverable cobalt in concentrates shipped reported by Statistics Canada. Data prior to 2019 are mineral production reported by Natural Resources Canada.

⁶Determined from reported or estimated cobalt content of materials originating from mining and processing operations in Congo (Kinshasa) such as ores, concentrates, refined cobalt metal, and intermediate products including crude cobalt alloys, crude cobalt hydroxide, and crude cobalt carbonate produced from cobalt ores and concentrates, tailings, or slags.

⁷Determined from estimated cobalt content of nickel-cobalt sulfide production and estimated cobalt content of ammoniacal liquor production.

⁸Determined from estimated cobalt content of nickel matte plus estimated cobalt content of nickel-cobalt hydroxide.

⁹Estimated cobalt content of ore production based on reported or estimated cobalt metal powder production and nickel recovery rates.

¹⁰Cobalt content of concentrate estimated from reported or estimated gross weight.

¹¹Cobalt content of nickel hydroxide. Data prior to 2021 include cobalt content of cobalt carbonate.

¹²Cobalt content of nickel-cobalt hydroxide.

¹³Cobalt content of nickel-cobalt sulfide.

¹⁴Cobalt content of concentrates.

¹⁵Cobalt content of cobalt carbonate and nickel-cobalt hydroxide.

TABLE 8
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY OR LOCALITY^{1,2}

(Metric tons, cobalt content)

Country or locality and form	2018	2019	2020	2021	2022
Australia, metal powder and oxide hydroxide	3,200	3,700	3,300	2,800	3,300
Belgium, metal powder, oxide, hydroxide ^{e,3}	1,650	1,500	1,300	700 ^r	--
Brazil, metal	8 ⁴	-- ⁵	-- ⁵	--	--
Canada, metal, metal powder, oxide	6,349	6,075	5,965	6,045	5,802
China, metal, metal powder, oxide, salts ^e	83,100	95,000	106,000	133,000 ^r	139,000
Congo (Kinshasa), metal ⁶	60	--	--	--	--
Finland, metal powder and salts ⁷	14,295	14,283	15,148	14,287 ^{r,8}	12,781
France, chloride	48 ⁴	90 ^e	90 ^e	110 ^e	153
India, metal and salts	100 ⁴	NA ⁹	NA ⁹	NA ⁹	NA ⁹
Japan, metal	3,669 ⁴	4,000 ^e	4,200 ^e	3,500 ^{e,3}	3,700 ^{e,3}
Madagascar, metal powder	2,852	2,897	833	2,111 ^r	3,000 ^e
Mexico, metal	226	215	190 ^e	220 ^e	110 ^e
Morocco, metal	1,806	2,397	2,416	1,796	1,690
Norway, metal	4,166	4,354	4,384	4,000	3,100
Russia, metal	1,800 ⁴	2,000 ^e	1,800 ³	1,500 ³	1,000 ^e
South Africa, metal powder and sulfate ^e	600 ^{r,3}	500 ^{r,3}	450 ^{r,3}	500 ^r	500
Zambia, metal	1,613 ⁴	1,500 ¹⁰	100 ¹⁰	--	-- ^e
Total	126,000	139,000	146,000 ^r	171,000 ^r	174,000

^eEstimated. ^rRevised. NA Not available. -- Zero.

¹Table includes data available through November 13, 2023. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

³Source: Darton Commodities Ltd.

⁴Source: Cobalt Institute (formerly Cobalt Development Institute).

⁵Source: Companhia Brasileira de Alumínio.

⁶Does not include production of cobalt in alloys, carbonate, hydroxide, and other materials that would require further refining.

⁷Source: Geological Survey of Finland.

⁸Does not include production of cobalt content of cobalt sulfate at Terrafame Ltd.'s nickel-cobalt refinery, which began production in June 2021.

⁹Refined cobalt may be produced from imported materials, but available information was inadequate to make reliable estimates of output.

¹⁰Source: Eurasian Resources Group.