



# 2019 Minerals Yearbook

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## COBALT [ADVANCE RELEASE]

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# COBALT

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In 2019, 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. Congo (Kinshasa) remained the leading producer of mined cobalt, supplying nearly 70% of world production, which decreased slightly in 2019 to 144,000 metric tons (t) of cobalt content (tables 1, 7).

The United States did not refine cobalt ores or concentrates in 2019. World production of refined cobalt increased for the third consecutive year, increasing by 6% to 132,000 t in 2019 from that in 2018 (tables 1, 8). The increase was mainly the result of higher production in China, where nearly 70% of the world's refined cobalt was produced.

In 2019, U.S. apparent consumption of cobalt increased by 63% from that in 2018, a result of net imports being nearly twice those in 2018 (table 1). Darton Commodities Ltd. (2019, p. 71; 2020, p. 58–59, 86) estimated that world consumption of refined cobalt increased by nearly 6% to 122,600 t, driven mainly by increased consumption in rechargeable batteries for electric vehicles. Based on its estimates of refined cobalt production and consumption, Darton Commodities estimated a global surplus of about 4,200 t of refined cobalt in 2019, compared with nearly 3,000 t in 2018.

Cobalt is a metallic element used in numerous, diverse commercial, industrial, and military applications. Globally, the leading use of cobalt was rechargeable batteries, followed by 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.

## Legislation and Government Programs

**Critical Minerals.**—In 2018, the U.S. Department of the Interior (DOI), in coordination with other executive branch agencies, published a list of 35 mineral commodities, including cobalt. In June 2019, the U.S. Department of Commerce released “A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals.” The Commerce strategy report had several recommendations for the DOI to take the lead or assist in achieving goals, including locating domestic sources of critical minerals, providing information for the study and

production of critical minerals, and evaluating regulations to provide timely processing of permit applications for mineral projects (U.S. Department of the Interior, Office of the Secretary, 2018; U.S. Department of Commerce, 2019, p. 10, 20, 24, 33–36, 40–43).

**National Defense Stockpile.**—The Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt in 2019. During the calendar year, the DLA Strategic Materials acquired 280 kilograms of lithium-nickel-cobalt-aluminum oxide. Calendar yearend National Defense Stockpile (NDS) inventories of cobalt materials are listed in table 1.

## Production

In 2019, three companies produced cobalt-bearing ore concentrates, and estimated U.S. mine production increased by 4% to 500 t from that in 2018 (tables 1, 7). Lundin Mining Corp. (Canada) produced copper and nickel sulfide concentrates from the Eagle nickel-copper mine northwest of Marquette, MI, and a mill in Humboldt Township, MI. In September, Lundin began ore extraction from the Eagle East deposit, approximately 2 kilometers east of the Eagle deposit. Eagle's nickel concentrates, which contained cobalt, were sent by rail to smelters in North America or to ports for shipment overseas (Lundin Mining Corp., 2020, p. 33–34, 37).

Missouri Cobalt, LLC built a beneficiation plant to reprocess tailings generated by previous mining of lead and other metals at the Madison Mine near Fredericktown, Madison County, MO. In 2019, the company began production of a bulk concentrate containing cobalt, copper, and nickel (M.R. Hollomon II, Chief Executive Officer, Missouri Cobalt, LLC, written commun., November 15, 2019; U.S. Environmental Protection Agency, 2019).

Sibanye Gold Ltd., trading as Sibanye-Stillwater, produced negligible amounts of cobalt in nickel sulfate at its PGM mining and refining operations in southeastern Montana. In recent years, the nickel sulfate was sold to other companies (Stillwater Mining Co., 2017, p. 21).

Jervois Mining Ltd. completed its acquisition of eCobalt Solutions Inc. assets by acquiring all of eCobalt's issued and outstanding shares that it did not already own. eCobalt's Idaho Cobalt project, west of Salmon in Lemhi County, ID, consisted of an environmentally permitted and partially constructed underground cobalt-copper-gold mine and beneficiation plant to produce separate cobalt and copper concentrates. Jervois considered the project to be its flagship project and renamed it the Idaho Cobalt Operations. During 2019, Jervois worked to update a feasibility study on the project and initiated a scoping study on refining the concentrates within the State. The company expected the studies to be completed by the end of March 2020 and, pending close of project financing, forecast a

12-month construction period, with first commercial production of concentrates during the second half of 2021 (Jervois Mining Ltd., 2019).

In March, PolyMet Mining Corp. received the Federal record of decision and wetlands permit from the U.S. Army Corps of Engineers, which were the last key approvals and permits needed for the company to construct and operate its NorthMet project in northeastern Minnesota. During the first phase of the project, PolyMet planned to mine the NorthMet copper-nickel-cobalt sulfide deposit in the Duluth Complex using open pit methods and produce a copper concentrate and a nickel concentrate containing approximately 150 metric tons per year (t/yr) of cobalt. PolyMet forecast that construction and rampup to commercial production would take approximately 30 months after receiving funding (PolyMet Mining Corp., 2020, p. 3–6, 18, 22–23, 32).

U.S. processors produced intermediate or marketable cobalt chemicals from refined cobalt materials and (or) cobalt-bearing scrap. U.S. Geological Survey (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.

Cobalt was recovered from secondary (scrap) materials by subsidiaries of Umicore N.V./S.A. (Belgium) and Plansee Group (Austria). The Umicore Specialty Chemicals plant in Arab, AL, recycled spent catalysts for its customers. In 2019, Umicore announced that, owing to a challenging market environment, it planned to discontinue operations at its Specialty Materials Recycling plant in Wickliffe, OH. The Wickliffe plant processed secondary materials such as superalloy scrap and recovered cobalt, nickel, and rhenium for the catalyst, petrochemical refining, and aviation industries. The recycling of cobalt-bearing scrap formerly done at Wickliffe would be transferred to Umicore's refinery in Olen, Belgium. Plansee Group's Global Tungsten & Powders Corp. (GTP) plant in Towanda, PA, recovered an intermediate cobalt chemical compound as a byproduct of tungsten recovery from cemented carbide scrap. GTP had a long-term agreement with Umicore whereby Umicore would toll process GTP's intermediate cobalt compound to cobalt metal powder (Global Tungsten & Powders Corp., 2014; Umicore N.V./S.A., 2020, p. 31; undated).

## Consumption

U.S. reported consumption of cobalt in 2019 was 3% less than that in 2018 (table 1). Metallurgical industries used 3% less cobalt, and chemical industries used slightly less cobalt than they did in 2018. Reported consumption statistics were derived by the USGS from voluntary surveys of U.S. operations. Most of the cobalt chemical-use data were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as cemented carbide, magnetic alloy, and superalloy producers. For this survey, about 50 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 2 include estimates based on prior reports or industry trends to account for nonrespondents.

U.S. apparent consumption for 2019, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, increased by 63% from apparent consumption (revised) in 2018 (table 1). The increase was a result of greater imports and fewer exports in 2019 compared with those in 2018. Discrepancies in volumes or trends between reported and apparent consumption can result from several situations, including consumers missing from USGS surveys, inaccurate estimates for nonresponding consumers on the surveys, and large unreported stock changes, such as materials imported or exported by trading firms, investors, and missing or nonresponding consumers.

## 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 \$16.95 per pound, less than one-half that of the peak in prices in 2018 (table 1). During the first 3 months of 2019, the Platts price continued the downward trend that began in May 2018. The Platts price decreased from \$44.00 to \$45.00 per pound in May 2018 to \$29.00 to \$30.00 per pound in early January 2019 and then reached a low of \$13.00 to \$14.00 per pound in mid-March. From May 2018 to the end of March 2019, the price dropped by 70%. From April through yearend 2019, the price fluctuated between a low of \$13.50 per pound in mid-June through mid-July and a high of \$19.00 per pound in September and was \$16.00 to \$16.50 per pound at yearend.

The decrease in cobalt prices in 2018 and 2019 was attributed to an oversupply of cobalt in the market and destocking of surplus cobalt materials that had built up throughout the supply chain. During 2017 through early 2018, expectations of significant increased future cobalt demand needed in electric vehicle batteries resulted in market actions responding to a concern of potential future supply shortages. Investment funds and investors purchased large quantities of cobalt metal during a period of tight supply, and prices increased with the growth in demand. The higher prices led to increased production throughout the supply chain, which exceeded actual consumption and resulted in excess supplies. After a period of destocking and decreasing prices, prices fluctuated within a narrower range during the second half of 2019. The market correction was in part the result of the reduction of some mine production in Congo (Kinshasa) in response to lower prices (Darton Commodities Ltd., 2019, p. 1, 4; 2020, p. 50–51, 85; China Molybdenum Co., Ltd., 2020, p. 61–62).

Cobalt metal with a minimum of 99.8% cobalt in the form of broken and cut cathode, ingots, rounds, and coarse-grain metal powder was traded on the London Metal Exchange Ltd. (LME). Sherritt International Corp. (2020a, p. 16) reported that the amount of cobalt traded in 2019 on the LME's physically settled contract decreased by 26% from that in 2018. Sherritt and the LME attributed the LME cobalt contract's continued lack of liquidity and low trading volumes as the reason for it remaining a secondary pricing mechanism (Radford, 2018). The annual average mean of cash-buyer and cash-seller prices and yearend LME inventory levels are listed in table 1.

In March, the LME launched a cash-settled futures contract for cobalt to complement its existing physically settled cobalt contract. In contrast to the physically settled contract, which delivered physical metal, the cash-settled contract transferred the cash value of the physical metal based on a reported price for standard-grade cobalt from Fastmarkets MB. In October, the LME announced responsible sourcing requirements for its listed brands, which were based on the Organisation for Economic Co-operation and Development's "Due Diligence Guidance for Responsible Supply Chains of Minerals From Conflict-Affected and High-Risk Areas" (London Metal Exchange Ltd., The, 2019, undated).

Cobalt also was traded on the China Stainless Steel Exchange, based in Wuxi, Jiangsu Province. At yearend, the city of Ganzhou, Jiangxi Province, launched an exchange for trading rare earths and minor metals, including cobalt (Darton Commodities Ltd., 2020, p. 53; Thomson Reuters, 2020).

In 2019, Pala Investments Ltd. acquired Cobalt 27 Capital Corp. and transferred some of Cobalt 27's assets to Conic Metals Corp. These assets included Cobalt 27's royalty contracts with potential Australian and Canadian nickel and (or) cobalt producers and its joint-venture interest in the Ramu nickel-cobalt operation in Papua New Guinea. Pala planned to keep Cobalt 27's physical cobalt inventory of about 2,900 t and its streaming contract with a subsidiary of Vale S.A. for cobalt from the Voisey's Bay operation in Canada (Cobalt 27 Capital Corp. and Pala Investments Ltd., 2019; Radford, 2019; Conic Metals Corp., 2020, p. 2–4, 7).

## Foreign Trade

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic production to meet demand. Net import reliance is defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were originally imported or produced in the United States. In 2019, net import reliance as a percentage of apparent consumption for cobalt was 78%. Because U.S. cobalt mine production was exported to be refined, this indicated that 78% of U.S. cobalt supply was from imports and stock releases of refined cobalt and 22% was from domestic or imported scrap.

The cobalt content of U.S. imports and exports was estimated based on gross weight data reported by the U.S. Census Bureau. In 2019, the United States imported a record level of 13,900 t of cobalt contained in metal and chemical compounds, valued at \$525 million, 16% more than the 11,900 t (revised) imported in 2018 (table 3). On the basis of cobalt content, 10 countries supplied 93% of U.S. imports in 2019. Norway was the leading supplier, followed by Canada, Japan, Madagascar, Russia, Finland, Australia, Belgium, China, and the United Kingdom (table 4). The U.S. Census Bureau also reported U.S. imports of the following materials: cobalt waste and scrap (2,100 t gross weight, valued at \$28.9 million), unwrought cobalt alloys (369 t gross weight, valued at \$23.6 million), and wrought cobalt and cobalt articles (491 t gross weight, valued at \$53.8 million).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 4,070 t, valued at \$132 million, 41% less than

the 6,950 t (revised) exported in 2018. On the basis of cobalt content, Canada was the leading destination for these exports, followed by Ireland, France, and Germany, each of which imported more than 200 t of cobalt from the United States (table 5). The U.S. Census Bureau also reported that the United States exported 1,750 t gross weight of wrought metal and cobalt articles valued at \$164 million.

## World Review

In 2019, world cobalt mine production decreased slightly compared with production in 2018. The decrease was the result of a 4,000-t decrease in estimated production in Congo (Kinshasa), the leading global producer of mined cobalt (table 7). In contrast, world cobalt refinery production increased by 6% compared with that in 2018, mainly owing to a 6,900-t increase in estimated production in China, the leading global producer of refined cobalt (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). Nonbyproduct (or primary) cobalt production included mine and refinery production in Morocco, artisanal mining of the mineral heterogenite 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 their 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.

Prompted by issues associated with artisanal mining of cobalt in Congo (Kinshasa), companies throughout the cobalt supply chain, governments, nongovernmental organizations, other stakeholders, and the media continued to focus attention on the sources of cobalt-containing raw materials and components with regard to ethical and sustainable production. A number of initiatives have been launched in recent years to promote responsible production and sourcing of cobalt (Darton Commodities Ltd., 2020, p. 44–45).

**Australia.**—In 2019, cobalt mine production as a byproduct of nickel and nickel-copper mining in Western Australia increased by 18%, and production of refined cobalt in Australia increased by 16% (tables 7, 8). Glencore plc's Murrin Murrin nickel-cobalt laterite mining and refining operation, operated by Minara Resources Ltd., was Australia's leading producer of mined cobalt and the sole producer of refined cobalt. Other producers of mined cobalt included BHP Group Ltd.'s Nickel West integrated nickel sulfide operation, Independence Group NL's Nova nickel-copper-cobalt sulfide mine, Panoramic Resources Ltd.'s Savannah nickel-copper-cobalt sulfide mine, and Western Areas Ltd.'s Forrestania nickel sulfide mining operation (Independence Group NL, 2019, p. 3; 2020, p. 3; Panoramic Resources Ltd., 2019, p. 3; 2020, p. 3; BHP Group Ltd., 2020, p. 12; Glencore plc, 2020, p. 239; Western Areas Ltd., 2020, p. 2).

First Quantum Minerals Ltd. (Canada) kept its Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant in Western Australia on care-and-maintenance status throughout the year. The company planned to restart production during the first quarter of 2020 and expected to produce intermediate nickel-cobalt hydroxide containing 15,000 to 20,000 t of nickel in 2020 that would contain an estimated 500 to 700 t of cobalt (First Quantum Minerals Ltd., 2020, p. 33).

**Belgium.**—Darton Commodities Ltd. (2020, p. 8, 18) estimated that Umicore's cobalt production at its Olen refinery in 2019 was 9% lower than production in 2018 (table 8). The refinery produced cobalt salts and oxides, mainly from intermediate materials sourced from other companies. In addition to the Olen refinery, Umicore refined various cobalt materials, including copper and cobalt concentrates, to produce cobalt oxides and salts in Ganzhou, Jiangxi Province, China. In late 2019, Umicore completed the purchase of Freeport Cobalt Oy's cobalt refinery and battery cathode precursor business at Kokkola, Finland. During 2019, Umicore entered into a long-term agreement with Glencore for the supply of crude cobalt hydroxide from Glencore's Kamoto Copper Company SA (KCC) and Mutanda Mining SPRL operations in Congo (Kinshasa); the hydroxide would be shipped to Umicore's refineries in Belgium, China, and Finland (Umicore N.V./S.A., 2019; 2020, p. 35).

**Brazil.**—Atlantic Nickel Mineração Ltda. restarted production at the Santa Rita open pit nickel-copper-cobalt sulfide mine and concentrator in Bahia State. The operation had been on care-and-maintenance status since 2016, when its former owner Mirabela Nickel Ltd. was placed under voluntary administration. By yearend 2019, Atlantic Nickel had produced and sold nickel concentrate (Appian Capital Advisory LLP, 2020).

Companhia Brasileira de Alumínio (a member of the Votorantim S.A. group) owned the nickel-cobalt laterite mining and processing operation in Niquelandia, Goiás State, and refinery at Sao Miguel Paulista, Sao Paulo State. In 2019, the operations remained suspended in response to low nickel prices (Companhia Brasileira de Alumínio, 2020, p. 11).

**Canada.**—In 2019, cobalt mine production as a byproduct of nickel mining in Canada increased slightly, and Canadian production of refined cobalt from domestic and imported feeds decreased by 4% (tables 7, 8).

Vale produced 1,583 t (1,630 t in 2018) of refined cobalt metal at its Long Harbour, Newfoundland and Labrador, refinery and 1,092 t (1,288 t in 2018) of refined cobalt metal at its Port Colborne, Ontario, refinery. Most of Vale's refined cobalt originated from company-owned nickel-sulfide and nickel-copper-sulfide mines. In 2019, 1,608 t (1,902 t in 2018) of cobalt was mined at Voisey's Bay in northeastern Labrador, 495 t (520 t in 2018) was mined at Sudbury, Ontario, and 80 t (198 t in 2018) was mined at Thompson, Manitoba (Vale S.A., 2020, p. 65).

Vale worked to extend the Voisey's Bay mine underground and increase the operation's average annual production to an estimated 45,000 t of nickel, 20,000 t of copper, and 2,600 t of cobalt. The project was 41% complete and was expected to start production in the first half of 2021 (Vale S.A., 2020, p. 87).

Glencore reported that 700 t (900 t in 2018) of the cobalt produced at its Nikkelverk refinery in Norway originated from

concentrates produced from its nickel sulfide mines at Sudbury, Ontario, and Raglan, Quebec (Glencore plc, 2020, p. 239).

The Fort Saskatchewan refinery, a joint venture of Sherritt and General Nickel Co. S.A., produced 3,376 t of cobalt as metal powder and briquettes in 2019, 4% more than the 3,234 t produced in 2018. Approximately 92% of the cobalt originated from Cuba and the remainder was from purchased materials. As a result of a United States embargo on imports of products originating from Cuba, cobalt and nickel produced by Sherritt could not be sold to customers in the United States (Sherritt International Corp., 2020a, p. 17, 61–63, 94).

First Cobalt Corp. finalized a loan agreement with Glencore for the next phase of work on its cobalt refinery near North Cobalt, Ontario. The proceeds were used for studies on recommissioning the refinery to produce battery-grade cobalt sulfate for the U.S. market and a feasibility study on expanding the refinery's production capacity. The refinery had been on care-and-maintenance status since 2015, prior to which it operated intermittently under several former owners following commissioning in 1996 (First Cobalt Corp., 2020, p. 6, 8, 14–15).

**China.**—China was the world's leading producer and consumer of refined cobalt. In 2019, China's estimated production increased by 8% from that in 2018 and represented more than two-thirds of world refined cobalt production (table 8). Most of production was in the form of cobalt salts (84%); the remainder was metal (10%) and metal powder (6%). China's consumption of refined cobalt increased to 69,000 t, 7% more than that in 2018, and nearly 82% of 2019 consumption was used to make cathode materials for rechargeable batteries (Roskill Information Services Ltd., 2019, p. 32; Cobalt and Cathode Material Monthly, 2020, p. 4, 16).

Numerous companies refined and (or) processed cobalt in China. In 2019, 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 decreasing order of estimated production. Only a small portion of China's cobalt production originated from domestic mines. Most of the production was from imported cobalt intermediate chemical compounds, the majority of which was sourced from Congo (Kinshasa). In 2019, China imported an estimated 84,000 t of cobalt in concentrates and intermediates, 24% more than that in 2018. China's imports of cobalt concentrates continued to decrease, and its imports of intermediate products continued to increase as more concentrates produced in Congo (Kinshasa) were processed to intermediates prior to export. With regard to refined cobalt, China's production, consumption, and net exports resulted in a surplus of about 9,800 t of contained cobalt in 2019 (Darton Commodities Ltd., 2020, p. 8, 57; Xu and others, 2020, p. 28, 31, 34).

**Congo (Kinshasa).**—Congo (Kinshasa) was the world's leading producer of mined cobalt and was estimated to represent nearly 70% of global production (table 7). Most of the country's cobalt mine production was from copper-cobalt ores mined by industrial or mechanized methods. The rest was gathered by tens of thousands of artisanal miners handpicking cobalt-rich ores. Artisanal mining provided needed income to miners and 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. As a result of lower cobalt prices and declining demand for artisanal ore, Darton Commodities Ltd. (2020, p. 44) estimated that artisanal mining decreased by about 60% from 17,000 to 19,000 t by cobalt content in 2018 to 7,000 to 8,000 t by cobalt content in 2019. In late 2019, the Government of Congo (Kinshasa) established *Entreprise Générale du Cobalt (EGC)* as a subsidiary of state-owned *La Générale des Carrières et des Mines SA (Gécamines)*. EGC was formed to improve the working conditions of artisanal miners by managing and controlling the production, purchasing, processing, and marketing of cobalt produced by artisanal methods (Mayiro, 2019).

Most of the ores and concentrates produced in Congo (Kinshasa) were processed domestically into crude cobalt hydroxide, an intermediate material. Some concentrates were exported and, in recent years, only small quantities were refined domestically into cobalt metal (table 8). Gécamines had been the sole producer of refined cobalt in the country since late 2015, when KCC halted production at its Luilu cobalt refinery. In 2019, no cobalt was thought to have been refined in Congo (Kinshasa). During the year, *Metal Mines SARL (Nanjing Hanrui Cobalt Co., Ltd.)* was building a plant to produce refined copper and cobalt in Kolwezi, Lualaba Province. The plant had a design capacity of 5,000 t/yr of electrolytic cobalt (cobalt cathode) (Katanga Mining Ltd., 2016, p. 1–2; SMM News, 2019; Darton Commodities Ltd., 2020, p. 38, 42–43).

In 2019, five companies accounted for 85% of Congo (Kinshasa)'s estimated cobalt mine production—*Glencore, China Molybdenum Co., Ltd. (CMOC), Huayou, Eurasian Resources Group S.a.r.l. (ERG)* (40% of which was owned by the Government of Kazakhstan), and *Shalina Resources Ltd. (United Arab Emirates)*, listed in descending order of reported or estimated production.

Glencore had majority ownership in two copper-cobalt mining and refining operations in Congo (Kinshasa)—*KCC* and *Mutanda*, both in Lualaba Province. In 2019, KCC produced 17,054 t of cobalt in hydroxide, 53% more than the 11,112 t produced in 2018. Mutanda produced 25,100 t of cobalt in concentrate and hydroxide, 8% less than the record high of 27,300 t produced in 2018. Production decreased at Mutanda because Glencore placed the operation on temporary care-and-maintenance status in late 2019 for several reasons, including low cobalt prices and an oversupplied market (Glencore plc, 2020, p. 8, 59, 70, 236; Katanga Mining Ltd., 2020, p. 6).

CMOC had majority ownership of *Tenke Fungurume Mining S.A.R.L.*'s copper-cobalt mining and refining operation in Lualaba Province. In 2019, Tenke Fungurume produced 16,098 t of cobalt in hydroxide, 14% less than the 18,747 t produced in 2018 (China Molybdenum Co., Ltd., 2020, p. 65).

Huayou subsidiary *Congo Dongfang International Mining S.P.R.L. (CDM)* sourced cobalt ores and (or) concentrates from Huayou's *La Minière de Kasombo S.P.R.L. (MIKAS)* copper-cobalt mining and processing operation, CDM's PE527 copper-cobalt mining project, and traders at artisanal and small-scale mines at Kasulo, Shabara, and Twiluzembe. Darton Commodities estimated combined production from CDM and MIKAS to be 9,600 t of cobalt in hydroxide in 2019,

a 12% decrease from the 10,900 t produced in 2018 (Darton Commodities Ltd., 2020, p. 11–12, 28, 34–35).

ERG had majority ownership in two operations in Congo (Kinshasa)—*Boss Mining SPRL* and *Metalkol Roan Tailings Reclamation*. Boss Mining produced copper-cobalt concentrates from ores extracted from open pit mines primarily at the Mukondo and Kabolela mines and from tailings generated during past mining operations within its license area and processed some of the concentrates into crude cobalt carbonate. In February, ERG announced that it was placing Boss Mining on care-and-maintenance status while it studied the feasibility of constructing two processing plants to treat copper-cobalt ores onsite. The decision also was likely influenced by depletion of copper-cobalt oxide ore, economic impacts from 2018 revisions to the mining code in Congo (Kinshasa), and a new 5% tax on imports of copper concentrates into Zambia, where Boss Mining sent most of its concentrates to be refined (Clowes and Farchy, 2019; Darton Commodities Ltd., 2020, p. 23, 36; Eurasian Resources Group S.a.r.l., 2020, p. 87).

ERG's Metalkol operation recovered copper and cobalt from tailings deposited in the Kingamyambo Tailings Dam and Musonoi River Valley in Haut Katanga Province during past mining operations. In 2019, the project's second year of operation, Metalkol ramped up production and produced a total of 8,400 t of cobalt in hydroxide, including 1,700 t consumed internally. During the year, ERG began construction on phase 2 of the project to increase Metalkol's production capacity from 14,000 t/yr of cobalt to 20,000 t/yr (Darton Commodities Ltd., 2020, p. 37; Eurasian Resources Group S.a.r.l., 2020, p. 10, 24–25).

Shalina's Chemaf SARL had two copper-cobalt mining operations and two refineries. Darton Commodities estimated that Chemaf produced 8,100 t of cobalt in hydroxide in 2019, an increase of 13% compared with the 7,200 t produced in 2018. Most of Chemaf's production was mined from its Etoile open pit mine and processed to crude cobalt hydroxide at an onsite refinery. In 2019, Chemaf operated a pilot project for responsible artisanal mining at the company's Mutoshi Mine in Kolwezi. All concentrates from this project were processed exclusively at Chemaf's Usoke refinery in Lubumbashi. During the year, Chemaf continued to build a refinery at the Mutoshi Mine site, which was to have the capacity to produce 16,000 t/yr of cobalt in hydroxide (Johansson de Silva and others, 2019, p. 6, 12–13, 34; Darton Commodities Ltd., 2020, p. 28, 35).

Most of the cobalt hydroxide produced in Congo (Kinshasa) was exported to refiners in China. In late 2018, KCC temporarily suspended export and sale of its cobalt hydroxide, after detecting uranium levels that exceeded allowable regulatory limits for export. In late April 2019, KCC resumed the export and sale of a limited quantity of cobalt hydroxide that complied with regulations. At yearend, KCC submitted a bankable feasibility study to the Ministry of Mines on the whole operation, which included long-term options for reducing the cobalt hydroxide's uranium levels (Darton Commodities Ltd., 2020, p. 42, 55; Glencore plc, 2020, p. 8, 59, 70, 236; Katanga Mining Ltd., 2020, p. 6, 22).

**Cuba.**—*Moa Nickel S.A.* (part of the 50–50 joint venture between Sherritt and General Nickel) mined nickel-cobalt

laterites at Moa, Holguin Province, and produced intermediate nickel-cobalt sulfide, which was sent to the joint venture's Fort Saskatchewan refinery in Canada. In 2019, the sulfide contained 34,021 t of nickel and cobalt, 3% less than the 35,125 t produced in 2018 (Sherritt International Corp., 2020a, p. 94).

The Government-owned Empresa Niquelífera Ernesto Che Guevara operation (also known as Punta Gorda) in Moa, Holguin Province, mined and processed nickel-cobalt laterites. The operation was undergoing a debottlenecking program to increase output to about 36,000 t/yr of contained nickel plus cobalt (Wood Mackenzie, 2019). Nickel and cobalt originating in Cuba could not be imported into the United States because of a United States embargo on imports from Cuba (U.S. Code, 2010).

**Finland.**—In 2019, Finland's production of refined cobalt was 3% less than that in 2018 (table 8). The Freeport Cobalt Oy (Freeport-McMoRan Inc., Lundin, and Gécamines) refinery at Kokkola consumed mainly crude cobalt hydroxide supplied under a long-term agreement by the Tenke Fungurume operation in Congo (Kinshasa). The refinery also processed cobalt-bearing scrap from the battery, catalyst, and cemented carbide industries. Late in the year, Freeport Cobalt completed the sale of the refinery and related battery cathode precursor business to Umicore. Freeport Cobalt retained the remaining cobalt business at the facility, which included the production of cobalt metal powders, chemicals, catalysts, ceramics, and pigments (Darton Commodities Ltd., 2020, p. 14; Freeport-McMoRan Inc., 2020, p. 22; Freeport Cobalt Oy, undated).

PJSC MMC Norilsk Nickel (Nornickel) (Russia) produced two cobalt products at its Harjavalta nickel refinery—refined cobalt sulfate and an intermediate cobalt sulfate solution. In 2019, most of the refinery's nickel feed was sourced from company operations in Russia (nickel matte and converter matte from Kola MMC); third-party feed included nickel matte from Boliden AB's Harjavalta smelter and nickel salts from other companies (PJSC MMC Norilsk Nickel, 2020, p. 16–17, 85–86).

Boliden produced 445 t of cobalt in nickel concentrate from its Kevitsa nickel-copper-PGM sulfide mine and beneficiation plant, compared with 591 t produced in 2018, and 425 t of cobalt in nickel-cobalt concentrate at its underground Kylylahti copper-zinc mine and beneficiation plant, an increase from the 278 t produced in 2018. The company planned to cease mining at Kylylahti in late 2020, owing to depletion of reserves, but was investigating the possibility of extracting cobalt from the mine's tailings. Boliden's Harjavalta smelter processed nickel concentrates from Kevitsa and elsewhere and sold the resulting nickel matte (Boliden AB, 2020, p. 27, 100, 114–115).

Terrafame Ltd. [majority owned by Finnish Minerals Group Ltd. (Government of Finland)] produced intermediate nickel-cobalt sulfide at its polymetallic mining and bioheap-leaching operation in Sotkamo, central Finland. In 2019, the sulfide was exported mainly to Asia to be refined and contained an estimated 550 t of cobalt, the same as that in 2018. During the year, Terrafame was constructing a refinery that would convert the sulfide into nickel sulfate and cobalt sulfate for battery applications. The refinery was to have the capacity to produce 7,400 t/yr of cobalt sulfate containing an estimated 1,550 t/yr of cobalt (Terrafame Ltd., 2020, p. 3, 6, 48, 51).

**France.**—Eramet s.a. produced cobalt chloride as a byproduct of nickel at its Sandouville refinery. The refinery nearly doubled its production of refined nickel, as it ramped up production following an upgrade necessitated by a planned change in feed composition. Since mid-2017, Eramet had purchased matte from Boliden's Harjavalta smelter under a long-term supply agreement (Thomson Reuters, 2016; Bories, 2020, p. 33).

**Indonesia.**—PT Vale Indonesia Tbk produced cobalt-bearing nickel matte from lateritic ores at its integrated mining and smelting operation near Sorowako on Sulawesi Island. The matte was committed to Vale Canada Ltd. (80%) and Sumitomo Metal Mining Co., Ltd. (20%) under life-of-mine agreements. Most of the matte sold to Vale was sent to the company's nickel refinery in Matsusaka, Mie Prefecture, Japan (Vale S.A., 2020, p. 57).

As part of the Indonesian Government's plan to process more nickel laterite ore domestically and to produce products for the battery industry, a number of companies were planning to build high-pressure acid leaching (HPAL) plants to process low-grade nickel, high-grade cobalt limonitic laterite ore (Shah, 2018).

**Japan.**—Sumitomo's Niihama nickel refinery in Ehime Prefecture processed intermediate nickel-cobalt sulfides from the Coral Bay Nickel Corp. and Taganito HPAL Nickel Corp. plants in the Philippines, nickel matte from PT Vale in Indonesia, and additional raw materials from elsewhere. The Niihama refinery produced cobalt chloride, most of which was converted to electrolytic cobalt (cobalt cathode) for sale (Darton Commodities Ltd., 2020, p. 20; Sumitomo Metal Mining Co., Ltd., 2020, p. 51, 53–54).

Sumitomo's Harima refinery in Hyogo Prefecture processed intermediate nickel-cobalt sulfides from Coral Bay Nickel and Taganito to produce cobalt chloride. Some of the cobalt chloride from Harima was sent to Sumitomo's Niihama refinery to be converted to metal. Some of Sumitomo's cobalt chloride (from Harima and Niihama) was sent to the company's Isoura battery materials plant in Niihama and its Sumiko Energy Materials Co., Ltd. plant in Fukushima to produce battery cathode materials (Darton Commodities Ltd., 2020, p. 20; Sumitomo Metal Mining Co., Ltd., 2020, p. 51, 54).

**Madagascar.**—Cobalt metal production from Madagascar's sole refinery, the Ambatovy joint venture (Sumitomo Corp., Korea Resources Corp., and Sherritt), increased slightly from that in 2018 (table 8). Sherritt was the operator of the joint venture, which mined nickel-cobalt laterite ore in east-central Madagascar and transported the ore by pipeline to a processing plant and refinery located near the Port of Toamasina (Sherritt International Corp., 2020b, p. 19).

**Mexico.**—Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (MMB) [Korean Consortium and Camrova Resources Inc. (Canada)] owned and operated the El Boleo project, which consisted of a copper-cobalt-zinc mine and refinery in Baja California Sur. In 2019, MMB produced 215 t of refined cobalt, a 5% decrease from the estimated 226 t produced in 2018 (Camrova Resources Inc., 2019, p. 4; 2020, p. 4).

**Morocco.**—Compagnie de Tifnout Tighanimine (CTT) (a subsidiary of Groupe Managem) mined cobalt arsenide ores and produced crude cobalt hydroxide at Bou-Azzer. The hydroxide was refined to electrolytic cobalt (cobalt cathode) at CTT's

Guemassa hydrometallurgical refinery north of Marrakech. In 2019, CTT's production of refined cobalt was 33% higher than that in 2018, following improvements in concentrate production and an increase in refinery capacity (table 6) (Groupe Managem, 2020, p. 59, 89).

**New Caledonia.**—In 2019, estimated recoverable mine production decreased by 19% compared with that in 2018 (table 7) because of a decrease in production from sole producer Vale Nouvelle-Calédonie S.A.S. (VNC) (Vale and Société de Participation Minière du Sud Caledonien S.A.S.). During the year, VNC's operation in the southern tip of New Caledonia's main island continued to experience production issues. Vale decided to decommission the operation's refinery to reduce operating costs and allow the company to focus on improving performance at the HPAL processing plant. Refining was scheduled to cease in early 2020, after which the operation would produce only nickel-cobalt hydroxide. By yearend 2019, Vale had decided to exit the VNC operation (New Century Resources Ltd., 2020; Vale S.A., 2020, p. 17, 57, 65).

**Norway.**—In 2019, Glencore's production of electrolytic cobalt (cobalt cathode) at Nikkelverk, Norway's sole refinery, was 5% more than that in 2018 (table 8). The company's Sudbury and Raglan operations in Canada supplied 16% of the cobalt refined at Nikkelverk; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies, reportedly including about 400 t of cobalt in intermediates from Nornickel (Darton Commodities Ltd., 2020, p. 16; Glencore plc, 2020, p. 239).

**Papua New Guinea.**—In 2019, the Ramu nickel-cobalt joint venture, operated by majority owner Metallurgical Corporation of China Ltd., produced 11% less cobalt in intermediate nickel-cobalt hydroxide than it did in 2018 (table 7). Nickel-cobalt hydroxide from the joint venture's Kurumbukari nickel-cobalt laterite mine and Basamuk HPAL processing plant was exported to China to be refined (Darton Commodities Ltd., 2020, p. 40, 55–56).

**Philippines.**—Two HPAL processing plants produced intermediate nickel-cobalt sulfides from lateritic ore mined in the Philippines—Coral Bay Nickel and Taganito. Coral Bay Nickel was a joint venture among Sumitomo, Mitsui & Co., Ltd., Sojitz Corp., and Rio Tuba Nickel Mining Corp., listed in order of share, with operations at the Rio Tuba Mine on Palawan Island. Taganito was a joint venture among Sumitomo, Mitsui, and Nickel Asia Corp., listed in order of share, with operations at Nickel Asia's Taganito Mine in the northeastern region of Mindanao Island. In 2019, production of intermediate nickel-cobalt sulfides from Coral Bay Nickel was reportedly about 5% lower than that in 2018, and production from Taganito was reportedly more than 20% higher following plant improvements and preventative maintenance. The mixed sulfides were sent to Sumitomo's Niihama and Harima refineries in Japan (Darton Commodities Ltd., 2020, p. 20; Sumitomo Metal Mining Co., Ltd., 2020, p. 51, 54).

**Russia.**—Production by Nornickel, the sole producer of refined cobalt in Russia, was estimated to have increased in 2019 from that in 2018 (table 8). The company mined and beneficiated copper-nickel sulfide ores and smelted the concentrates at its Polar Division on the Taymyr Peninsula and

at Kola MMC on the Kola Peninsula. Matte from the Polar Division was refined at Kola MMC's Severonickel refinery at Monchegorsk on the Kola Peninsula. Matte from Kola MMC was refined at Severonickel and at Norilsk Nickel Harjavalta Oy in Finland. The Severonickel refinery produced three grades of electrolytic cobalt (cobalt cathode) and crude cobalt hydroxide. In 2019, Nornickel reportedly produced about 1,800 t of cobalt in hydroxide, which was sent to the company's Harjavalta refinery, Glencore's Nikkelverk refinery, and to other processors in Belgium and the United Kingdom (Khodov, 2019; Darton Commodities Ltd., 2020, p. 24; PJSC MMC Norilsk Nickel, 2020, p. 16–17, 76–82).

**South Africa.**—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Nornickel) produced 737 t of cobalt in nickel concentrate in calendar year 2019 (746 t in 2018). Concentrate from Nkomati was sold to Metal Trade Overseas AG (African Rainbow Minerals Ltd., 2019, p. 63; 2020, p. 13).

Cobalt also was produced as a byproduct from some of South Africa's PGM operations. Two companies produced refined cobalt. Rustenburg Base Metals Refiners (Proprietary) Ltd. (a subsidiary of Anglo American plc) produced cobalt sulfate at its base-metals refinery near Rustenburg, North West Province (Anglo American Platinum Ltd., 2020, p. 18, 92). Impala Platinum Holdings Ltd. (Implats) produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province. In addition to refining concentrates from PGM ore mined in South Africa, some of the cobalt produced by Implats was recovered from concentrates produced at the Mimosa platinum mine in Zimbabwe.

Two other platinum producers—Lonmin Plc and Northam Platinum Ltd.—operated base-metals refineries that processed materials containing nickel and cobalt. In June, Sibanye-Stillwater acquired Lonmin and renamed it the Marikana operation. Thakadu Battery Materials Pty. Ltd. was building a plant at the Marikana base-metals refinery to refine the operation's crude sulfate to battery-grade nickel sulfate and byproduct cobalt hydroxide (Northam Platinum Ltd., 2019, p. 11, 41; Sibanye Stillwater Ltd., 2019, p. 3, 9; Thakadu Group, 2021).

**Turkey.**—Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. (Vestel Elektronik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) produced intermediate nickel-cobalt hydroxide containing 1,790 t of nickel metal equivalent and an estimated 120 t of cobalt from its HPAL processing plant at Gordes, Manisa Province. Production in 2019 was less than the 5,001 t of nickel and 259 t of cobalt produced in 2018, owing to planned downtime and fewer operating days at the plant, which used local nickel-cobalt laterite ore as feed. During the year, Meta Nikel worked to increase the number of operational days with the target of reaching full production capacity of 10,000 t/yr of nickel and 550 t/yr of cobalt in the future. The company also planned investments to produce value-added nickel sulfate and cobalt sulfate products and to construct a new facility to double its capacity to produce nickel-cobalt hydroxide and nickel and cobalt sulfates (Vestel Elektronik Sanayi ve Ticaret A.Ş., 2020, p. 112–114, 256).



In late 2018, Eti Bakir A.Ş. (Cengiz Holding A.Ş.) reportedly began recovering cobalt from calcine generated from roasting pyrite to produce sulfuric acid. In 2019, Eti Bakir produced an estimated 500 t of cobalt as crude cobalt carbonate from a newly installed recovery circuit at its Mazıdaği phosphate plant in Mardin Province (Metso Outotec Corp., 2019; Darton Commodities Ltd., 2021, p. 9–10, 83).

**Zambia.**—According to the Zambian Ministry of Mines and Mineral Development, in 2019, production of mined cobalt was one-half that in 2018 (table 7). Production of refined cobalt was 7% less than that in 2018 (table 8). Chambishi Metals (ERG and ZCCM Investments Holdings Plc) was Zambia's sole producer of refined cobalt and used imported feed from ERG operations in Congo (Kinshasa). The company suspended production at the refinery in early 2019 following the introduction of a 5% tax on imported copper concentrates, then restarted production midyear using cobalt hydroxide from ERG's Metalkol operation in Congo (Kinshasa) (Darton Commodities Ltd., 2020, p. 23; Eurasian Resources Group S.a.r.l., 2020, p. 10).

Two companies mined copper-cobalt ore in Zambia and recovered cobalt in intermediate materials. Konkola Copper Mines Plc (KCM) [Vedanta Resources Ltd. (India) and Government-owned ZCCM Investments Holdings Plc (ZCCM-IH)] processed concentrates from its Zambian mining operations and from other sources, including mines in Congo (Kinshasa), at its Nchanga copper smelter. Cobalt was recovered to an intermediate copper-iron-cobalt alloy. In May, ZCCM-IH ordered the liquidation of KCM's assets and appointed a provisional liquidator to continue the business of KCM and take possession and dispose of its assets. Vedanta challenged the liquidation and requested that its dispute with ZCCM-IH be handled by arbitration. The dispute had not been resolved by yearend (Hunter and Luk, 2019; ZCCM Investments Holdings Plc, 2021).

China Nonferrous Mining Corp. Ltd. (CNMC) mined and processed copper-cobalt ore in the Zambian Copperbelt through various majority-owned subsidiaries. During the first half of 2019, CNMC suspended production of intermediate copper-cobalt alloy at its Chambishi Copper Smelter to overhaul the furnace. As a result, only minimal cobalt in alloy was produced during the year (China Nonferrous Mining Corp. Ltd., 2019, p. 20; 2020, p. 27–29).

In early 2019, Mabiza Resources Ltd., a subsidiary of Consolidated Nickel Mines Ltd. (CNM) (United Kingdom), restarted production at the Munali nickel sulfide mine in southern Zambia. The main product of the mine was to be nickel concentrate containing 5,000 t/yr of nickel, 200 t/yr of cobalt, plus copper and PGMs (Pole, 2018; Mabiza Resources Ltd., 2019).

**Zimbabwe.**—Bindura Nickel Corporation Ltd., Implats and Sibanye Gold Ltd., and Zimplats Holdings Ltd. generated small quantities of byproduct cobalt from their nickel and platinum mining operations.

## Outlook

Historically, trends in refined cobalt consumption closely followed those of global industrial production. Increases in cobalt consumption by the battery industry, mainly for personal

electronics, have resulted in global annual growth rates in cobalt consumption exceeding growth rates for the global gross domestic product. During the 11-year period between 2007 and 2017, cobalt consumption increased at a compound annual growth rate of 5.7%. This rate was forecast to increase to 9.5% between 2018 and 2025 and to be 12.4% between 2020 and 2025, driven mainly by cobalt's use in rechargeable lithium-ion batteries for electric vehicles (Darton Commodities Ltd., 2019, p. 71–72; 2021, p. 37).

The general consensus is that global cobalt supply is forecast to continue to increase. Cobalt mine and intermediate production could increase significantly in the near term, particularly from mines and processing plants in Congo (Kinshasa). These include the rampup of production of from KCC's 40,000-t/yr (cobalt content) whole ore leach operation and phase 1 of ERG's 14,000-t/yr (cobalt content) Metalkol RTR operation, the restart of Glencore's 27,000-t/yr (cobalt content) Mutanda Mine, and the startup of Chemaf's 16,000-t/yr (cobalt content) Mutoshi operation. HPAL plants constructed at nickel laterite operations in Indonesia also could produce significant amounts of cobalt. Production from these and other, smaller projects could provide enough cobalt raw materials to result in surplus cobalt supply in the near term. Beyond 2021, however, additional new supply is expected to be needed to meet the predicted increase in cobalt consumption for electric vehicles (Shah, 2018; Darton Commodities Ltd., 2019, p. 26–27, 29–30, 34, 40, 71–72; Heathman, 2019, p. 3, 12; Glencore plc, 2020, p. 236).

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TABLE 1  
SALIENT COBALT STATISTICS<sup>1</sup>

(Metric tons, cobalt content, unless otherwise specified)

	2015	2016	2017	2018	2019	
<b>United States:</b>						
Mine production <sup>c</sup>	760	690	640	480 <sup>r</sup>	500	
<b>Consumption:</b>						
Reported	8,830	9,010	9,240	9,290 <sup>r</sup>	9,050	
Apparent <sup>2</sup>	10,300	11,500	8,950 <sup>r</sup>	7,700 <sup>r</sup>	12,500	
Imports for consumption	11,400	12,800	11,900	11,900 <sup>r</sup>	13,900	
Exports	3,830	4,160	5,690 <sup>r</sup>	6,950 <sup>r</sup>	4,070	
<b>Stocks, December 31:</b>						
Industry <sup>3</sup>	1,070	969	1,020	1,060 <sup>r</sup>	1,090	
London Metal Exchange Ltd. (LME), U.S. warehouses	165	195	160	130	102	
<b>U.S. Government:<sup>4</sup></b>						
Metal	301	301	302	302	302	
Lithium-cobalt oxide	(5)	(5)	1	1	1	
Lithium-nickel-cobalt-aluminum oxide	do.	1	2	2	2	
Cobalt alloys	do.	--	(5)	3	3	
<b>Price, metal:</b>						
U.S. spot <sup>6</sup>	dollars per pound	13.44	12.01	26.97	37.43	16.95
LME, cash <sup>7</sup>	do.	12.90	11.57	25.28	32.94	14.88
<b>World:</b>						
<b>Production:<sup>c</sup></b>						
Mine	122,000	112,000	126,000 <sup>r</sup>	148,000	144,000	
Refinery	99,800	96,700 <sup>r</sup>	117,000	125,000	132,000	
Stocks, December 31, LME <sup>8</sup>	630	691	580	863	685	

<sup>c</sup>Estimated. <sup>r</sup>Revised. do. Ditto. -- Zero.

<sup>1</sup>Table includes data available through November 24, 2020. Data are rounded to no more than three significant digits, except prices.

<sup>2</sup>Defined as imports minus exports plus adjustments for Government and industry stock changes plus secondary production, as estimated from consumption of purchased scrap.

<sup>3</sup>Stocks held by cobalt processors and consumers.

<sup>4</sup>Source: Defense Logistics Agency Strategic Materials.

<sup>5</sup>Less than ½ unit.

<sup>6</sup>Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by S&P Global Platts Metals Week.

<sup>7</sup>Annual 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.

<sup>8</sup>Stocks held in Asia, Europe, and the United States.

TABLE 2  
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT<sup>1,2</sup>

(Metric tons, cobalt content)

	2018	2019
Consumption by end use:		
Steels and other alloys, excludes superalloys <sup>3</sup>	1,390	1,230
Superalloys	4,240	4,220
Cemented carbides <sup>4</sup>	800 <sup>r</sup>	799
Chemical and ceramic uses	2,860 <sup>r</sup>	2,800
Total	9,290 <sup>r</sup>	9,050
Consumption by form:		
Chemical compounds, organic and inorganic <sup>5</sup>	2,210 <sup>r</sup>	2,150
Metal	4,330	4,150
Purchased scrap	2,750 <sup>r</sup>	2,750
Total	9,290 <sup>r</sup>	9,050
Stocks, December 31: <sup>6</sup>		
Chemical compounds, organic and inorganic <sup>5</sup>	430	488
Metal	W	W
Purchased scrap	W	W
Total	1,060 <sup>r</sup>	1,090

<sup>r</sup>Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

<sup>1</sup>Table includes data available through October 5, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Includes estimates.

<sup>3</sup>Includes magnetic alloys, nonferrous alloys, wear- and corrosion-resistant alloys, welding materials, and other metallic uses not listed.

<sup>4</sup>Includes cast carbide dies or parts, cemented and sintered carbides, and diamond tool matrices.

<sup>5</sup>Includes oxides.

<sup>6</sup>Stocks held by cobalt processors and consumers.

TABLE 3  
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM<sup>1</sup>

Form	HTS <sup>2</sup> codes	2018			2019		
		Gross weight (metric tons)	Cobalt content <sup>3</sup> (metric tons)	Value <sup>4</sup> (thousands)	Gross weight (metric tons)	Cobalt content <sup>3</sup> (metric tons)	Value <sup>4</sup> (thousands)
Metal <sup>5</sup>	8105.20.6000, 8105.20.9000	9,300 <sup>r</sup>	9,300 <sup>r</sup>	\$627,000 <sup>r</sup>	11,900	11,900	\$453,000
Oxides and hydroxides	2822.00.0000	1,690	1,210	92,000	1,710	1,230	44,300
Other:							
Acetates	2915.29.3000	341	82	3,090	97	23	1,110
Carbonates	2836.99.1000	801	369	20,000	729	335	16,400
Chlorides	2827.39.6000	91 <sup>r</sup>	23 <sup>r</sup>	1,800 <sup>r</sup>	128	32	1,500
Sulfates	2833.29.1000	3,430	927	17,200	1,150	312	8,840
Total		15,700 <sup>r</sup>	11,900 <sup>r</sup>	761,000 <sup>r</sup>	15,800	13,900	525,000

<sup>r</sup>Revised.

<sup>1</sup>Table includes data available through July 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Harmonized Tariff Schedule of the United States.

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

<sup>4</sup>Customs value.

<sup>5</sup>Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 4  
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY OR LOCALITY<sup>1</sup>

Country or locality	Metal <sup>2</sup>			Oxides and hydroxides <sup>3</sup>			Other forms <sup>4</sup>			Total		
	Quantity (metric tons)		Value <sup>6</sup> (thousands)	Quantity (metric tons)		Value <sup>6</sup> (thousands)	Quantity (metric tons)		Value <sup>6</sup> (thousands)	Quantity (metric tons)		Value <sup>6</sup> (thousands)
	Gross weight	Cobalt content <sup>5</sup>		Gross weight	Cobalt content <sup>5</sup>		Gross weight	Cobalt content <sup>5</sup>		Gross weight	Cobalt content <sup>5</sup>	
2018:												
Australia	578	578	\$38,300	1	1	\$27	--	--	--	579	579	\$38,300
Belgium	36	36	3,320	628	452	35,500	29	8	\$143	693	496	39,000
Brazil	4	4	248	9	6	376	586	162	2,700	599	172	3,330
Canada	1,820	1,820	122,000	1	1	49	4	1	13	1,830	1,820	122,000
China	812	812	64,800	361	260	18,600	749 <sup>r</sup>	241 <sup>r</sup>	9,610 <sup>r</sup>	1,920 <sup>r</sup>	1,310	93,000 <sup>r</sup>
Finland	641	641	47,500	295	213	15,000	2,910	873	25,700	3,850	1,730	88,200
Germany	45	45	2,620	2	1	59	--	--	--	46	46	2,680
Hong Kong	46	46	3,760	--	--	--	--	--	--	46	46	3,760
Japan	1,760	1,760	125,000	(7)	(7)	3	--	--	--	1,760	1,760	125,000
Madagascar	798	798	65,200	--	--	--	--	--	--	798	798	65,200
Morocco	210	210	16,400	--	--	--	--	--	--	210	210	16,400
Norway	1,630 <sup>r</sup>	1,630 <sup>r</sup>	92,900 <sup>r</sup>	--	--	--	--	--	--	1,630 <sup>r</sup>	1,630 <sup>r</sup>	92,900 <sup>r</sup>
Russia	544	544	36,200	--	--	--	--	--	--	544	544	36,200
South Africa	287	287	4,260	--	--	--	11	5	382	298	292	4,640
Taiwan	--	--	--	30	22	1,210	--	--	--	30	22	1,210
United Kingdom	57	57	2,740	340	245	20,200	312	92	2,680	709	394	25,700
Other	29	29	1,700	19	14	864	63	19	954	111	61	3,520
Total	9,300 <sup>r</sup>	9,300 <sup>r</sup>	627,000 <sup>r</sup>	1,690	1,210	92,000	4,670 <sup>r</sup>	1,400	42,200 <sup>r</sup>	15,700 <sup>r</sup>	11,900 <sup>r</sup>	761,000 <sup>r</sup>
2019:												
Australia	725	725	33,700	--	--	--	--	--	--	725	725	33,700
Belgium	59	59	2,640	561	404	15,700	33	9	179	653	472	18,500
Brazil	20	20	710	--	--	--	186	57	1,570	206	77	2,280
Canada	2,400	2,400	88,000	--	--	--	3	1	57	2,400	2,400	88,100
China	213	213	10,500	221	159	5,650	163	46	2,000	598	418	18,200
Finland	471	471	18,300	293	211	7,770	1,470	507	20,900	2,230	1,190	46,900
Germany	49	49	2,470	--	--	--	21	9	692	69	58	3,160
Japan	1,400	1,400	52,800	1	1	23	3	1	33	1,410	1,400	52,900
Korea, Republic of	(7)	(7)	20	147	106	2,100	(7)	(7)	8	148	106	2,120
Madagascar	1,380	1,380	57,400	--	--	--	--	--	--	1,380	1,380	57,400
Mexico	45	45	1,400	--	--	--	(7)	(7)	11	45	45	1,410
Morocco	339	339	12,100	--	--	--	--	--	--	339	339	12,100
Norway	3,270	3,270	126,000	--	--	--	--	--	--	3,270	3,270	126,000
Russia	1,220	1,220	42,100	--	--	--	6	2	17	1,220	1,220	42,200
South Africa	307	307	2,570	--	--	--	--	--	--	307	307	2,570
Taiwan	1	1	53	74	54	1,970	6	1	67	82	56	2,090
United Kingdom	39	39	1,450	411	296	11,200	164	52	1,940	614	386	14,500
Other	11	11	730	(7)	(7)	7	56	17	424	67	28	1,160
Total	11,900	11,900	453,000	1,710	1,230	44,300	2,110	702	27,900	15,800	13,900	525,000

See footnotes at end of table.

TABLE 4—Continued  
 U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY OR LOCALITY<sup>1</sup>

<sup>1</sup>Revised. -- Zero.

<sup>2</sup>Table includes data available through July 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>3</sup>Unwrought 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.

<sup>4</sup>HTS code 2822.00.0000.

<sup>5</sup>Cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates under HTS codes 2827.39.6000, 2833.29.1000, 2836.99.1000, and 2915.29.3000.

<sup>6</sup>Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; carbonates, 46%; chlorides, 25%; and sulfates, 27%.  
<sup>7</sup>Customs value.

<sup>8</sup>Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 5  
U.S. EXPORTS OF COBALT, BY COUNTRY OR LOCALITY<sup>1,2</sup>

Country or locality	Metal <sup>3</sup>		Oxides and hydroxides <sup>4</sup>		Acetates <sup>5</sup>		Chlorides <sup>6</sup>		Total	
	Gross weight (metric tons)	Value <sup>7</sup> (thousands)	Gross weight (metric tons)	Value <sup>7</sup> (thousands)	Gross weight (metric tons)	Value <sup>7</sup> (thousands)	Gross weight (metric tons)	Value <sup>7</sup> (thousands)	Cobalt content <sup>8</sup> (metric tons)	Value <sup>7</sup> (thousands)
2018	6,840 <sup>r</sup>	\$172,000	69	\$2,810	278	\$4,460	1	\$25	6,950 <sup>r</sup>	\$180,000 <sup>r</sup>
2019:										
Argentina	8	452	--	--	--	--	--	--	8	452
Australia	29	486	(9)	8	--	--	--	--	29	494
Belgium	48	1,430	40	490	138	1,570	--	--	110	3,480
Brazil	71	2,540	(9)	16	--	--	--	--	72	2,560
Canada	1,080	10,900	20	677	--	--	--	--	1,100	11,600
China	125	5,710	--	--	--	--	--	--	125	5,710
Finland	4	404	--	--	--	--	--	--	4	404
France	585	19,000	--	--	--	--	--	--	585	19,000
Germany	317	19,200	1	56	--	--	(9)	4	318	19,200
Hong Kong	8	951	--	--	--	--	--	--	8	951
India	49	2,690	1	11	20	152	--	--	55	2,860
Ireland	858	31,900	--	--	--	--	--	--	858	31,900
Italy	8	1,220	(9)	21	--	--	--	--	9	1,250
Japan	105	5,270	--	--	--	--	--	--	105	5,270
Korea, Republic of	171	4,160	--	--	--	--	--	--	171	4,160
Malaysia	7	1,420	--	--	--	--	--	--	7	1,420
Mexico	6	570	16	413	45	644	(9)	4	28	1,630
Netherlands	66	2,580	--	--	--	--	--	--	66	2,580
Saudi Arabia	7	618	--	--	--	--	--	--	7	618
Singapore	70	4,040	(9)	5	--	--	--	--	70	4,040
South Africa	5	259	--	--	--	--	--	--	5	259
Switzerland	11	583	--	--	--	--	--	--	11	583
Taiwan	57	1,890	--	--	--	--	--	--	57	1,890
Tunisia	37	1,210	--	--	--	--	--	--	37	1,210
Turkey	39	1,660	--	--	--	--	--	--	39	1,660
United Kingdom	153	5,020	--	--	--	--	--	--	153	5,020
Vietnam	23	592	--	--	--	--	--	--	23	592
Other	17	1,420	(9)	14	--	--	--	--	18	1,430
Total	3,970	128,000	79	1,710	203	2,360	(9)	9	4,070	132,000

<sup>r</sup>Revised. -- Zero.

<sup>1</sup>Table includes data available through July 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

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

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

<sup>4</sup>Schedule B code 2822.00.0000.

<sup>5</sup>Schedule B code 2915.29.3000.

<sup>6</sup>Schedule B code 2827.39.6000.

<sup>7</sup>Free alongside ship value.

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

<sup>9</sup>Less than ½ unit.

Source: U.S. Census Bureau.



TABLE 6  
WORLD ANNUAL COBALT REFINERY  
CAPACITY, DECEMBER 31, 2019<sup>1,2</sup>

(Metric tons, cobalt content)

Country or locality	Capacity
Australia	6,700
Belgium	3,000 <sup>e</sup>
Brazil	2,000
Canada	8,020
China	150,000
Congo (Kinshasa)	6,050 <sup>e</sup>
Finland	16,500
France	400
India	2,060 <sup>e</sup>
Japan	5,500 <sup>e</sup>
Madagascar	5,600
Mexico	1,700
Morocco	2,800
Norway	5,200
Russia	7,520 <sup>e</sup>
South Africa	2,900 <sup>e</sup>
Uganda	720
Zambia	9,600
Total	236,000 <sup>e</sup>

<sup>e</sup>Estimated.

<sup>1</sup>Table includes data available through September 29, 2020. Data are rounded to no more than three significant digits; may not add to total shown.

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

TABLE 7  
COBALT: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY<sup>1,2</sup>

(Metric tons, cobalt content)

Country or locality <sup>3</sup>	2015	2016	2017	2018	2019
Australia <sup>4</sup>	5,721	5,140	5,034	4,878	5,742
Botswana <sup>5</sup>	316	248	--	--	--
Brazil	2,771	852 <sup>r</sup>	185 <sup>r</sup>	-- <sup>e</sup>	30 <sup>e</sup>
Canada <sup>6</sup>	4,339	4,216	3,704	3,279 <sup>r</sup>	3,336
China <sup>e</sup>	2,600	2,300	2,500	2,000	2,500
Congo (Kinshasa) <sup>e,7</sup>	72,000	68,000	80,000	104,000	100,000
Cuba <sup>e,8</sup>	4,000	3,900	3,900	3,500	3,800
Finland <sup>9</sup>	440 <sup>e</sup>	690 <sup>e</sup>	1,000 <sup>e</sup>	1,377	1,454
Indonesia <sup>e,10</sup>	1,300	1,200	1,200	1,200	1,100
Madagascar <sup>e,11</sup>	4,000	3,800	3,600	3,300	3,400
Mexico <sup>e</sup>	--	980	1,000	1,400	1,100
Morocco <sup>e,12</sup>	1,500	1,600	2,300	2,300 <sup>r</sup>	2,300
New Caledonia <sup>e,13</sup>	3,640	3,390	2,780	2,100	1,700
Papua New Guinea <sup>14</sup>	2,505	2,191	3,308	3,275	2,911
Philippines <sup>e,15</sup>	4,300	4,000	4,600	4,750 <sup>r,16</sup>	5,100 <sup>16</sup>
Russia <sup>e,17</sup>	6,200	5,500	5,900	6,100	6,300
South Africa <sup>e</sup>	3,000 <sup>r</sup>	2,300	2,300	2,300	2,100
Turkey <sup>14</sup>	NA	100 <sup>e</sup>	220	259	120 <sup>e</sup>
United States <sup>e,17</sup>	760	690	640	480 <sup>r</sup>	500
Vietnam <sup>17</sup>	277	134	--	--	--
Zambia	1,700 <sup>e</sup>	600 <sup>e</sup>	990	835 <sup>r</sup>	420
Zimbabwe	355	409	445	403	400 <sup>e</sup>
Total <sup>e</sup>	122,000	112,000	126,000 <sup>r</sup>	148,000	144,000

<sup>e</sup>Estimated. <sup>r</sup>Revised. NA Not available. -- Zero.

<sup>1</sup>Table includes data available through November 24, 2020. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

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

<sup>3</sup>In addition to the countries listed, Spain may have produced cobalt, but available information was inadequate to make reliable estimates of output. Other 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.

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

<sup>5</sup>Reported cobalt content of pelletized nickel-copper matte.

<sup>6</sup>Recoverable cobalt in ores and concentrates shipped.

<sup>7</sup>Determined 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.

<sup>8</sup>Determined from estimated cobalt content of nickel-cobalt sulfide production and estimated cobalt content of ammoniacal liquor production.

<sup>9</sup>Data prior to 2018 exclude cobalt in low-grade cobalt-nickel concentrates that were stockpiled while a marketable product was being developed.

<sup>10</sup>Estimated cobalt content of nickel matte plus estimated cobalt in lateritic ore processed in Australia.

<sup>11</sup>Estimated cobalt content of ore production based on reported cobalt metal powder production and nickel recovery rates.

<sup>12</sup>Cobalt content of concentrate estimated from reported gross weight.

<sup>13</sup>Cobalt contained in cobalt chloride produced in France from New Caledonian matte, cobalt carbonate and nickel hydroxide produced in New Caledonia, and lateritic nickel ore exported to Australia.

<sup>14</sup>Cobalt content of nickel-cobalt hydroxide.

<sup>15</sup>Cobalt contained in nickel-cobalt sulfide produced in the Philippines and lateritic nickel ore exported to Australia.

<sup>16</sup>Source: Darton Commodities Ltd.

<sup>17</sup>Cobalt content of concentrates.

TABLE 8  
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY OR LOCALITY<sup>1,2</sup>

(Metric tons, cobalt content)

Country or locality and form	2015	2016	2017	2018	2019
Australia, metal powder and oxide hydroxide <sup>3</sup>	5,150	3,350 <sup>e,4</sup>	3,000	3,200	3,700
Belgium, metal powder, oxide, hydroxide <sup>e,5</sup>	1,500	1,500	1,600	1,650	1,500
Brazil, metal <sup>3</sup>	1,300	400	46	8	-- <sup>e</sup>
Canada, metal, metal powder, oxide	6,126	6,302	6,355	6,349 <sup>r,6</sup>	6,075 <sup>6</sup>
China, metal, metal powder, oxide, salts <sup>e</sup>	53,500	49,900	75,000	83,100	90,000
Congo (Kinshasa), metal <sup>7</sup>	3,141	50	120	60	-- <sup>e</sup>
Finland, metal powder and salts <sup>8</sup>	9,615	12,393	12,222	12,874	12,526
France, chloride <sup>3</sup>	133	119	277	48	90 <sup>e</sup>
India, metal and salts <sup>3</sup>	150	100	100	100	100 <sup>e</sup>
Japan, metal <sup>3</sup>	4,259	4,305	4,159	3,669	3,800 <sup>e</sup>
Madagascar, metal powder	3,464	3,273	3,053	2,852	2,900
Mexico, metal	--	419	420 <sup>e</sup>	226	215
Morocco, metal	1,982	2,081	1,924	1,806	2,397
Norway, metal	3,117 <sup>r</sup>	3,541 <sup>r</sup>	3,473 <sup>r</sup>	4,166 <sup>r</sup>	4,354
Russia, metal <sup>3</sup>	2,040	3,092	2,077	1,800	2,000 <sup>e</sup>
South Africa, metal powder and sulfate <sup>3</sup>	1,362 <sup>r,9</sup>	1,101	1,062	1,089	1,000 <sup>e</sup>
Zambia, metal <sup>3</sup>	2,997	4,725	2,520	1,613	1,500 <sup>10</sup>
Total <sup>e</sup>	99,800	96,700 <sup>r</sup>	117,000	125,000	132,000

<sup>e</sup>Estimated. <sup>r</sup>Revised. -- Zero.

<sup>1</sup>Table includes data available through November 12, 2020. All data are reported unless otherwise noted. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

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

<sup>3</sup>Source: Cobalt Institute (formerly Cobalt Development Institute), except as noted.

<sup>4</sup>Includes estimated production by Queensland Nickel Pty. Ltd. reported by Darton Commodities Ltd.

<sup>5</sup>Source: Darton Commodities Ltd.

<sup>6</sup>Excludes cobalt oxide.

<sup>7</sup>Does not include production of cobalt in alloys, carbonate, hydroxide, and other materials that would require further refining.

<sup>8</sup>Source: Geological Survey of Finland.

<sup>9</sup>Source: Department of Mineral Resources.

<sup>10</sup>Source: Eurasian Resources Group.