



2020 Minerals Yearbook

COBALT [ADVANCE RELEASE]

COBALT

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In 2020, 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. In 2020, world production of mined cobalt decreased by 7% to 142,000 metric tons (t) owing to several factors. The Mutanda Mine in Congo (Kinshasa) closed in late 2019 after producing 25,100 t of cobalt, or 16% of world mine production that year. Artisanal mining in Congo (Kinshasa) decreased in response to factors discussed in the Congo (Kinshasa) section. Other mining and processing operations reduced production either because of government-mandated shutdowns to avoid the spread of the coronavirus disease 2019 (COVID-19) virus or because of low cobalt prices and reduced consumption as a result of sharp declines in industrial activity and passenger air travel during the COVID-19 pandemic. The decreases in production outweighed increased production from mines that began or were ramping up production in 2020 (tables 1, 7; Cobalt Institute, 2021, p. 12; Darton Commodities Ltd., 2021, p. 4, 7–9, 35; Glencore plc, 2021, p. 161, 228; Argus Media Group, 2022, p. 43; Project Blue Group Ltd., The, 2022, p. 15).

The United States did not refine cobalt ores or concentrates in 2020. World production of refined cobalt decreased by 3% to 130,000 t in 2020. China remained the leading producer of refined cobalt, supplying nearly 70% of the world total (tables 1, 8). In 2020, world production of refined cobalt chemicals was estimated to have increased compared with production in 2019, and world production of refined cobalt metal (including coarse metal powder) was estimated to have remained unchanged or to have decreased compared with that in 2019 (Darton Commodities Ltd., 2021, p. 15–16; Project Blue Group Ltd., The, 2022, p. 21).

In 2020, U.S. apparent consumption of cobalt decreased by 32% from that in 2019, a result of decreases in net imports and secondary production, which was estimated from scrap consumption (tables 1, 2). Analysts differed in their estimates of the change in world consumption of refined cobalt from 2019 to 2020. These estimates ranged from consumption in 2020 being essentially unchanged from that in 2019 to consumption in 2020 being 6% more than that in 2019. Consumption in 2020 was characterized by an increase in cobalt consumption in rechargeable batteries for electric vehicles, portable electronics, and other applications, in contrast to a decrease in consumption by all other industries combined. Estimates of yearend cobalt supply-demand scenarios ranged from the market being in deficit to being roughly in balance to being in surplus (Cobalt Institute, 2021, p. 3–6; Darton Commodities Ltd., 2021, p. 35, 65; S&P Global Market Intelligence, 2021; Project Blue Group Ltd., The, 2022, p. 1, 6–7).

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.

Government Actions and Legislation

Critical Minerals.—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 2018, cobalt was included in a list of 35 critical minerals published by the U.S. Department of the Interior in coordination with other executive branch agencies (Trump, 2017; U.S. Department of the Interior, Office of the Secretary, 2018).

In October, the Critical Materials Institute of the U.S. Department of Energy (DOE) selected three research and development projects involving cobalt to receive funding as part of its goal to support early-stage research to help expand U.S. critical material supply recovered from domestic ores and scrap. In one of the projects, the Colorado School of Mines and First Cobalt Corp. (Canada) would collaborate to develop an improved beneficiation process to increase the cobalt grade of concentrates produced from ore mined from First Cobalt's Iron Creek deposit in central Idaho. In a second project, Doe Run Resources Co., in collaboration with the Missouri University of Science and Technology and OLI Systems, Inc., planned to develop a new economic process to recover cobalt and other valuable metals from ore. In a third project, Garrison Minerals LLC would collaborate with Big Blue Technologies LLC, Irish Metals LLC, Retrieval Technologies, Inc., and Telex Metals, LLC to evaluate an innovative and, if successful, more economical way to recycle lithium-ion batteries (U.S. Department of Energy, Critical Materials Institute, 2020).

National Defense Stockpile.—The Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt in 2020. During the calendar year, the DLA Strategic Materials acquired 800 kilograms (kg) of lithium-nickel-cobalt-aluminum oxide

and 8 t gross weight of cobalt alloys. Calendar yearend National Defense Stockpile (NDS) inventories of cobalt materials are listed in table 1.

Production

In 2020, three companies produced cobalt-bearing ore mineral concentrates in the United States. Estimated U.S. mine production increased by 20% to 600 t from that in 2019 (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. Eagle's nickel concentrates, which contained cobalt, were sent by rail to be smelted in Canada (Lundin Mining Corp., 2021, p. 34–35, 37).

Missouri Cobalt, LLC produced a bulk concentrate containing cobalt, copper, and nickel minerals by reprocessing tailings from previous mining of lead and other metals at the Madison Mine near Fredericktown, Madison County, MO. In 2020, the company produced refined cobalt at a pilot-scale hydrometallurgical plant in Earth City, MO (M.R. Hollomon II, Chief Executive Officer, Missouri Cobalt, LLC, written commun., May 10, 2021; PRNewswire, 2021).

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

In 2020, Jervois Mining Ltd. (Australia) released an updated bankable feasibility study on its 100%-owned Idaho Cobalt Operations (ICO) project, west of Salmon in Lemhi County, ID. The operation would process approximately 1,090 metric tons per day of cobalt-copper-gold ore from an underground mine over a period of 7 years to produce a bulk concentrate containing 2,900 metric tons per year (t/yr) of copper, 1,915 t/yr of cobalt, and 210 kg (6,700 troy ounces) per year of gold. Jervois had an approved plan of operations and the environmental permits needed to proceed with construction and operation of the proposed mine and beneficiation plant. To assist with assessing marketing and refining options, Jervois also evaluated the cost of producing separate copper and cobalt concentrates and a calcined cobalt concentrate. In addition, Jervois had an agreement to acquire the Sao Miguel Paulista nickel-cobalt refinery in Sao Paulo, Brazil, which would give the company the option to produce refined cobalt from ICO concentrate. Pending financing, Jervois planned to order long-lead-time equipment and to begin detailed engineering, early site work, and construction so that first commercial production could begin in mid-2022 (Jervois Mining Ltd., 2020, p. 2–4, 18–20, 23–24).

During the year, various permits and approvals granted to PolyMet Mining Corp. (Canada) for its NorthMet project in 2018 and 2019 by the Minnesota Department of Natural Resources, the Minnesota Pollution Control Agency, and the U.S. Army Corp of Engineers faced legal challenges brought by environmental and tribal organizations. These challenges delayed PolyMet's plan to construct and operate an open pit mine at the NorthMet copper-nickel-cobalt sulfide deposit in the Duluth Complex in northeastern Minnesota that would produce a copper concentrate

and a nickel concentrate containing about 150 t/yr of cobalt. The company continued to discuss debt and equity financing to fund permit litigation, project optimization, and construction. PolyMet forecast that construction and rampup to commercial production would take approximately 30 months after receiving funding (PolyMet Mining Corp., 2021, p. 4–6, 8, 33).

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). In 2020, Umicore closed its Specialty Materials Recycling plant in Wickliffe, OH, where secondary materials such as superalloy scrap had been processed to recover cobalt, nickel, and rhenium for the aviation, catalyst, and petrochemical refining industries. The recycling of cobalt-bearing scrap formerly done at Wickliffe would be transferred to Umicore's refinery in Olen, Belgium. In September, Umicore announced that it planned to discontinue operations at the Umicore Specialty Chemicals plant in Arab, AL, and consolidate its remaining U.S. activities at its Palm Commodities International, Inc. plant near Nashville, TN. In addition to recycling spent catalysts, the Arab operation produced a wide range of cobalt and nickel chemicals (Umicore N.V./S.A., 2020a, p. 31; 2020b; 2021, p. 33; undated a).

Plansee'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).

Consumption

U.S. estimated consumption of cobalt in 2020 was 20% less than that in 2019 (tables 1, 2). Cobalt consumption in metallurgical industries was estimated to have decreased by 23%, and cobalt consumption in chemical industries decreased by an estimated 14% from that in 2019. Estimated 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, 52 cobalt consumers were canvassed on a monthly or annual basis. 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 2020, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, decreased by 32% from apparent consumption in 2019 (table 1). The decrease was a result of lower net imports and less consumption from scrap in 2020, compared with those in 2019 (tables 1, 2).

Discrepancies in volumes or trends between reported and apparent consumption can result from several situations, including consumers missing from USGS surveys, the degree of uncertainty in consumption and stock estimates for nonresponding consumers on the surveys, and any misclassified trade data.

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 \$15.70 per pound, 7% less than that in 2019 (table 1). During the year, the weekly spot price fluctuated within a narrow range with the lowest price of \$13.50 to \$14.00 per pound in late July and the highest price of \$18.00 to \$18.75 per pound during a brief spike in prices that took place in mid- to late-March.

Cobalt metal with a minimum of 99.8% cobalt in the form of briquettes, broken and cut cathode, coarse-grain metal powder, and rounds was traded under a physically settled contract on the London Metal Exchange Ltd. (LME). Sherritt International Corp. (2021, p. 17) cited the LME cobalt contract's continued lack of liquidity as the reason for the LME price not being the preferred reference price for the negotiation and settlement of companies' physical contracts. Instead, the Fastmarkets MB standard-grade cobalt price continued to be the primary pricing mechanism used by companies for their contracts. During the year, the daily LME cash mean price fluctuated within a narrow range, with a high of \$15.65 per pound on January 31 and a low of \$12.47 per pound on March 12–13. The annual average mean of cash buyer and cash seller prices and yearend LME inventory levels are listed in table 1.

The LME also had a cash-settled futures contract for cobalt. 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 December, CME Group (a merger of the Chicago Mercantile Exchange and the Chicago Board of Trade in Chicago, the New York Mercantile Exchange in New York City, and the Kansas City Board of Trade) launched a cash-settled cobalt futures contract on Commodity Exchange, Inc. (known as the COMEX exchange). Like the LME cash-settled contract, CME Group's contract was indexed to the reported price for standard-grade cobalt from Fastmarkets MB (CME Group, 2020; Spilker, 2021; London Metal Exchange Ltd., The, undated).

Cobalt metal was traded in China on the China Stainless Steel Exchange, based in Wuxi, Jiangsu Province. In August, the exchange announced that it planned to launch a contract for trading cobalt sulfate. At yearend 2019, the city of Ganzhou in Jiangxi Province launched the Ganzhou Rare Metal Exchange for trading cobalt, rare earths, and other minor metals (Thomson Reuters, 2020a; Zou, 2020; Darton Commodities Ltd., 2021, p. 30).

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 2020, net import reliance as a percentage of apparent consumption for cobalt was 76%. Because U.S. cobalt mine production was exported to be refined, this indicated that 76% of U.S. cobalt supply was from imports and stock releases of refined cobalt and 24% 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 2020, U.S. imports of cobalt contained in metal and chemical compounds were 9,740 t, valued at \$336 million, 30% less than the 13,900 t imported in 2019 (table 3). On the basis of cobalt content, nine countries supplied 91% of U.S. imports in 2020. Canada was the leading supplier, followed by Norway, Japan, Finland, Australia, Russia, Madagascar, the United Kingdom, and Morocco (table 4). The U.S. Census Bureau also reported U.S. imports of the following materials, in gross weight: cobalt waste and scrap (1,430 t valued at \$15.2 million), unwrought cobalt alloys (272 t valued at \$12.8 million), and wrought cobalt and cobalt articles (319 t valued at \$44.4 million) (Shedd, 2021).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 3,440 t, valued at \$104 million, 16% less than the 4,080 t (revised) exported in 2019. On the basis of cobalt content, Canada was the leading destination for these exports, followed by Ireland, Germany, France, and the United Kingdom, 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 1,380 t gross weight of wrought metal and cobalt articles valued at \$143 million, a decrease from 1,750 t gross weight valued at \$164 million in 2019, and 150 t gross weight of cobalt ores and concentrates valued at \$521 million compared with 102 t gross weight valued at \$603 million in 2019 (Shedd, 2021).

World Review

In 2020, world cobalt mine production decreased by 7% compared with production in 2019 (table 7). The decrease was mainly the result of an estimated 9,000-t decrease in production in Congo (Kinshasa), the leading global producer of mined cobalt. World cobalt refinery production decreased by 3% compared with that in 2019. Apart from Finland and Japan, which each had increases in production of refined cobalt, production from every country was less than or essentially unchanged from that in 2019 (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 concerns that child labor, corruption, crime, environmental damage, hazardous working conditions, and unfair trading practices can be 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., 2021, p. 21–22; Cobalt Institute, undated a, b).

Australia.—In 2020, Australia was the third-ranked cobalt-producing country or locality in the world in terms of mine output and sixth-ranked in terms of refinery output. Cobalt mine production as a byproduct of nickel and nickel-copper mining in Western Australia decreased slightly compared with that in 2019, and production of refined cobalt in Australia decreased by 11% (tables 7, 8).

Glencore plc's (Switzerland) 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, which was in the form of coarse powder and briquettes. Other producers of mined cobalt included BHP Group Ltd.'s Nickel West integrated nickel sulfide operation, First Quantum Minerals Ltd.'s (Canada) Ravensthorpe nickel-cobalt laterite mining and processing operation, IGO Ltd.'s (formerly Independence Group NL) 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. In 2020, Panoramic decided to temporarily suspend operations at the Savannah Mine and First Quantum restarted production at Ravensthorpe, which had been placed on care-and-maintenance status in October 2017 in response to low nickel prices (Panoramic Resources Ltd., 2020; BHP Group Ltd., 2021, p. 15; Cobalt Institute, 2021, p. 17; First Quantum Minerals Ltd., 2021, p. 10, 13, 61; Glencore plc, 2021, p. 232; IGO Ltd., 2021, p. 4; Western Areas Ltd., 2021, p. 2).

Belgium.—Darton Commodities Ltd. (2021, p. 15, 86) estimated that Umicore's 2020 cobalt production from its Olen refinery was 13% lower than that in 2019 (table 8). The refinery, which was the sole producer of refined cobalt in Belgium, had the capability to produce a variety of cobalt oxides, salts, and cobalt metal powders. Umicore's production was mainly from intermediate materials sourced from other companies, which included a long-term agreement with Glencore for the supply of crude cobalt hydroxide from Glencore operations in Congo (Kinshasa) to Umicore's refineries in Olen; Ganzhou, Jiangxi Province, China; and Kokkola, Finland. In September, Umicore announced that it planned to move the cobalt refining and some of the cobalt transformation activities from Olen to its Kokkola refinery by mid-2023 (Umicore N.V./S.A., 2019, 2020b).

Brazil.—Atlantic Nickel Mineração Ltda. ramped up production at the Santa Rita open pit nickel-copper-cobalt sulfide mine and concentrator in Bahia State. The operation restarted production in late 2019 after being on care-and-maintenance status since 2016 when its former owner, Mirabela Nickel Ltd., was placed under voluntary administration. At full capacity, the mine was expected to produce 18,000 to 20,000 t/yr of nickel and an estimated 350 t/yr of cobalt (Rostas, 2020; Appian Capital Advisory LLP, 2021).

Companhia Brasileira de Alumínio (CBA), (a member of the Votorantim S.A. group) kept its nickel-cobalt laterite mine and processing operation in Niquelandia, Goiás State, and its Sao Miguel Paulista refinery in Sao Paulo State on care-and-maintenance status. In September, Jervois announced that it had reached an agreement with CBA to acquire the refinery, which had the capacity to produce 25,000 t/yr of electrolytic nickel (cathode) and 2,000 t/yr of electrolytic cobalt (cathode). Jervois planned to commission the refinery using nickel-cobalt hydroxide (often called mixed hydroxide precipitate or MHP) and crude cobalt hydroxide, then add a pressure oxidation leach circuit to process cobalt concentrate from its ICO project in the United States and concentrates from other operations (Companhia Brasileira de Alumínio, 2021, p. 14; Jervois Mining Ltd., 2021, p. 14–16).

Canada.—In 2020, Canada ranked sixth in global cobalt mine production and third in global cobalt refinery production. Canada's cobalt mine production, which was a byproduct of nickel mining, decreased by 7% from that in 2019, and Canadian production of refined cobalt from domestic and imported feeds decreased slightly (tables 7, 8).

Vale S.A. produced 1,582 t (1,583 t in 2019) of electrolytic cobalt (rounds) at its Long Harbour, Newfoundland and Labrador, refinery and 878 t (1,092 t in 2019) of electrolytic cobalt (rounds) at its Port Colborne, Ontario, refinery. Most of Vale's refined cobalt was produced from company-owned nickel-sulfide mines. In 2020, 1,591 t (1,608 t in 2019) of cobalt was from ore mined at Voisey's Bay in northeastern Labrador, 453 t (495 t in 2019) was mined at Sudbury, Ontario, and 60 t (80 t in 2019) from ore mined at Thompson, Manitoba (Vale S.A., 2020a, p. 65; 2021, 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 60% complete and was expected to start production in the first half of 2021 (Vale S.A., 2021, p. 88).

Glencore's Canadian Integrated Nickel Operations included nickel sulfide mines at Sudbury, Ontario, and Raglan, Quebec, and a smelter at Sudbury, which processed ore concentrates and secondary (scrap) nickel- and cobalt-bearing materials, including alloy scrap, battery materials, plating residues, and spent catalysts. In 2020, Glencore reported that 600 t (700 t in 2019) of the cobalt produced at its Nikkelverk refinery in Norway originated from concentrates produced at its Canadian nickel mines, and approximately 2,000 t of the cobalt produced at Nikkelverk originated from secondary materials processed at the Sudbury smelter (Glencore plc, 2021, p. 50, 69).

In 2020, The Cobalt Refinery Company Inc. [part of the 50–50 joint venture of Sherritt and General Nickel Co.

S.A. (Cuba)] produced 3,370 t of cobalt as metal powder and briquettes at its refinery in Fort Saskatchewan, Alberta, unchanged from the 3,376 t produced in 2019. Sherritt reported that nickel and cobalt production in 2020 were negatively affected by a disruption in railway service, an extended plant shutdown, unplanned repairs to the autoclaves, and reduced availability of contractors owing to COVID-19. Approximately 95% of the joint venture's cobalt originated from its Cuban mining and processing operation, 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., 2021, p. 9, 18, 72).

First Cobalt worked towards restarting its cobalt refinery near North Cobalt, Ontario, which had been on care-and-maintenance status since 2015. In May, First Cobalt announced the results of an engineering study on expanding the refinery that determined that it could produce 25,000 t/yr of battery-grade cobalt sulfate (approximately 5,000 t/yr of contained cobalt) using crude cobalt hydroxide feed. By November, First Cobalt had changed its commercial arrangement with Glencore from a tolling agreement to a long-term feed purchase contract, which would result in First Cobalt having ownership of the cobalt sulfate it produced. First Cobalt estimated that production could begin in late 2022, subject to finalizing project financing and receiving final permit amendment approvals, so that detailed engineering could be completed and construction could begin during the quarter ending September 2021 (Ausenco Engineering Canada Inc., 2020, p. 1; First Cobalt Corp., 2021, p. 6–7, 9–10, 15).

China.—China was the world's leading producer and consumer of refined cobalt. In 2020, China's estimated production was unchanged from that in 2019 and represented nearly 70% of world refined cobalt production. Most production was in the form of cobalt salts (84%), and the remainder was as metal and metal powder (16%). China's consumption of refined cobalt increased to 78,700 t, 7% more than that in 2019, and 82% of China's 2020 consumption was used to make cathode materials for rechargeable batteries (table 8; Cobalt Institute, 2021, p. 17; Darton Commodities Ltd., 2021, p. 26; Lithium Battery Metal Materials Monthly, 2021a, p. 1).

Numerous companies refined and (or) processed cobalt in China. In 2020, 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 sources. Domestic mine production was estimated to represent 1% of China's cobalt raw material supply, recycled scrap was estimated to represent 15%, and imported raw materials, 84%. Most of China's refinery production was from imported intermediate cobalt chemical compounds, the majority of which were sourced from Congo (Kinshasa). In 2020, China imported 3,670 t of cobalt in concentrate, 42% less than that imported in 2019 and nearly 77,000 t of cobalt in intermediate materials, a slight decrease from that imported in 2019. China's imports of cobalt concentrates have trended downward and its imports of intermediate products have trended upward as more concentrates

produced in Congo (Kinshasa) were processed to intermediates prior to export. With regard to refined cobalt, in 2020, China imported 6,192 t of cobalt metal, nearly three times that imported in 2019. The increase in metal imports was attributed to the availability of cobalt metal at prices below Fastmarkets MB prices and prices in the Chinese market. Also contributing to increased imports was an increase in the use of cobalt metal briquettes as an alternative to crude cobalt hydroxide for the battery sector after an extended lockdown in South Africa to prevent the spread of COVID-19 disrupted shipments of cobalt materials produced in Congo (Kinshasa) (Darton Commodities Ltd., 2021, p. 7, 15, 26, 30, 33–34; Lithium Battery Metal Materials Monthly, 2021b, p. 4–5).

In September and late December, China's State Reserve Bureau (SRB) invited Chinese cobalt producers and state-owned trading companies to participate in sales of cobalt metal to SRB's stockpile. Although the amounts to be purchased were not announced, market participants estimated that SRB secured 2,000 t of cobalt metal in September 2020 and an additional 3,000 t in late December 2020 (Darton Commodities Ltd., 2021, p. 32).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt. In 2020, Congo (Kinshasa)'s estimated production decreased by 8% and represented nearly 70% 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. As mentioned above, 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 2020, efforts continued to formalize the artisanal mining sector to promote ethical and sustainable cobalt production. In 2020, cobalt production by artisanal mining was estimated to have decreased from that in 2019, accounting for 7,000 to 8,500 t of contained cobalt, which was less than 10% of the cobalt mined in Congo (Kinshasa) in 2020. The decrease was attributed to increasing cobalt supply from large-scale mining operations; low cobalt prices; logistical disruptions and restrictions resulting from the COVID-19 pandemic; the closure of Chemaf SARL's Mutoshi artisanal mining project; decisions by large-scale mechanized mining companies and leading Chinese refiner Huayou to stop sourcing artisanally mined cobalt owing to environmental, social, and governance concerns; and the formation of a state monopoly to manage artisanal production (table 7; Cobalt Institute, 2021, p. 10, 12; undated b; Darton Commodities Ltd., 2021, p. 8–9, 20–21; Project Blue Group Ltd., The, 2022, p. 18).

Entreprise Générale du Cobalt (EGC), a subsidiary of state-owned La Générale des Carrières et des Mines SA (Gécamines), was established in late 2019 to improve the working conditions of artisanal miners by managing and controlling production, purchasing, processing, and marketing of cobalt produced by artisanal methods. In late 2020, EGC signed an offtake agreement with a subsidiary of trading company Trafigura

Group Pte. Ltd. (Singapore). Under the agreement, Trafigura would finance the creation of strictly controlled artisanal mining zones, the installation of ore-purchasing stations, and the costs related to transparent and traceable delivery of crude cobalt hydroxide to Trafigura. EGC was responsible for ensuring that the cobalt supplied under the agreement complied with Organisation for Economic Co-operation and Development due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas (Mayiro, 2019; Trafigura Group Pte. Ltd., 2020)

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 the past 5 years only small quantities have been refined domestically into cobalt metal (table 8). Gécamines had been the sole producer of refined cobalt in the country since late 2015, when Kamoto Copper Company SA (KCC) (Glencore, 75%; Gécamines, 20%; and Simco Sarl, 5%) ceased production at its Luilu cobalt refinery. During 2019 and 2020, no cobalt was thought to have been refined into cobalt metal in Congo (Kinshasa). In 2019, Hanrui Metal Congo S.A.R.L., a wholly owned subsidiary of Nanjing Hanrui Cobalt Co., Ltd. of China, completed construction of a copper refinery in Kolwezi, Lualaba Province, which included planned capacity to produce 5,000 t/yr of electrolytic cobalt (cathode). By yearend 2020, construction and commissioning of the cobalt circuit had not been completed because of delays resulting from the COVID-19 pandemic. Hanrui Cobalt expected to commence production of refined cobalt by September 2021 (Katanga Mining Ltd., 2016, p. 1–2; Darton Commodities Ltd., 2021, p. 20; Nanjing Hanrui Cobalt Co., Ltd., 2021, p. 34).

In 2020, three companies accounted for approximately 60% 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 China Molybdenum Co., Ltd. (CMOC).

Glencore had majority ownership in two copper-cobalt mining and refining operations in Congo (Kinshasa)—KCC and Mutanda, both in Lualaba Province. In 2020, KCC produced crude cobalt hydroxide containing 23,900 t of cobalt, 40% more than the 17,100 t produced in 2019. No production took place in 2020 at Mutanda, which had been placed on temporary care-and-maintenance status in late 2019 because of low cobalt prices and an oversupplied market (Glencore plc, 2021, p. 161, 228).

ERG had majority ownership in two copper-cobalt operations in Congo (Kinshasa)—Boss Mining SPRL, which remained on care-and-maintenance status in 2020, and Metalkol Roan Tailings Reclamation. 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 2020, Metalkol's production of salable crude cobalt hydroxide increased by 146% to 17,000 t of contained cobalt, making it the second ranked producer after KCC. During the year, ERG completed construction on phase 2 of the project, which increased Metalkol's production capacity to 20,000 t/yr of cobalt (Eurasian Resources Group S.a.r.l., 2021, p. 12, 25; undated).

CMOC had majority ownership of Tenke Fungurume Mining S.A.R.L.'s copper-cobalt mining and refining operation in Lualaba Province. In 2020, Tenke Fungurume produced crude cobalt hydroxide containing 15,436 t of cobalt, 4% less than the 16,098 t produced in 2019 (China Molybdenum Co., Ltd., 2020, p. 38; 2021, p. 23).

Shalina Resource Ltd.'s (United Arab Emirates) Chemaf S.A.R.L. produced crude cobalt hydroxide from two refineries. Concentrate produced at Chemaf's Etoile Mine near Lubumbashi was processed at an onsite refinery. Ore from Chemaf's Mutoshi Mine at Kolwezi was mined as part of a pilot project for responsible artisanal mining and processed at Chemaf's Usoke refinery in Lubumbashi. In April, Chemaf announced that it had halted the pilot project at Mutoshi, would place the Usoke plant under care-and-maintenance status, and suspend construction of a refinery with the capacity to produce 16,000 t/yr of cobalt in crude cobalt hydroxide at Mutoshi. The actions were in response, in part, to operational difficulties resulting from the COVID-19 pandemic (Thomson Reuters, 2020d; Darton Commodities Ltd., 2021, p. 79).

Cuba.—In 2020, Cuba ranked fifth in terms of global cobalt mine production. Moa Nickel S.A. (part of the 50–50 joint venture of Sherritt and General Nickel) mined nickel-cobalt laterites at its mining concessions in Holguin Province and produced intermediate nickel-cobalt sulfide (often called mixed sulfide precipitate or MSP), which was sent to the joint venture's Fort Saskatchewan refinery in Canada. The MSP contained 34,858 t of nickel and cobalt in 2020, slightly more than the 34,021 t produced in 2019 (table 7; Sherritt International Corp., 2021, p. 71–72).

The Government-owned Empresa Niquelífera Ernesto Che Guevara operation in Punta Gorda, Holguin Province, also 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, 2022). 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 2020, cobalt was recovered as a byproduct from three mining operations, one smelter, and two refineries. Boliden AB produced 495 t of cobalt in nickel concentrate from its open pit Kevitsa nickel-copper-PGM sulfide mine and beneficiation plant compared with 445 t in 2019, and 447 t of cobalt in nickel-cobalt concentrate at its underground Kylylahti copper-zinc mine and beneficiation plant compared with 425 t in 2019. In late 2020, the company ceased mining at Kylylahti, owing to depletion of reserves. Boliden's Harjavalta smelter processed nickel concentrates from Kevitsa and elsewhere and sold the resulting nickel matte. During the year, Boliden made an investment to expand the feed capacity of the nickel line at the smelter (Boliden AB, 2020; 2021, p. 16–18, 59, 113–114).

Terrafame Ltd. [majority owned by Finnish Minerals Group Ltd. (Government of Finland)] produced MSP at its polymetallic mining and bioheap-leaching operation in Sotkamo, central Finland. Cobalt production was estimated based on reported nickel production. In 2020, Terrafame produced an estimated 580 t of cobalt in MSP compared with 550 t in 2019. During the year, Terrafame continued to construct a refinery to convert MSP

into nickel sulfate and cobalt sulfate for battery applications. The refinery was expected to commence operation in the first half of 2021 and to have the capacity to produce 7,400 t/yr of cobalt sulfate containing an estimated 1,550 t/yr of cobalt at full production (Terrafame Ltd., 2021, p. 3, 14, 23).

Finland continued to be the second-ranked global producer of refined cobalt (table 8). The cobalt was produced at Umicore's refinery at Kokkola (formerly owned by Freeport-McMoRan Inc., Lundin, and Gécamines) and the PJSC MMC Norilsk Nickel (Norinickel) (Russia) nickel refinery at Harjavalta. The main feed for the Kokkola refinery was 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. It produced a wide range of cobalt chemicals and metal powders (Darton Commodities Ltd., 2021, p. 91; Umicore N.V./S.A., undated b).

Nornickel produced two cobalt products at its Harjavalta refinery—refined cobalt sulfate and an intermediate cobalt sulfate solution. The refinery processed nickel matte and converter matte from Kola MMC in Russia, nickel converter matte from Boliden's Harjavalta smelter, and nickel salts from other companies (PJSC MMC Norilsk Nickel, 2021, p. 94).

France.—Eramet s.a. produced cobalt chloride as a byproduct of nickel at its Sandouville refinery. Since mid-2017, Eramet had purchased matte from Boliden's Harjavalta smelter under a long-term supply agreement (Thomson Reuters, 2016; Eramet s.a., 2021, p. 65–66).

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., 2021, 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, at least five high-pressure acid leaching (HPAL) plants were reportedly under construction in 2020. The plants would process low-grade nickel, high-grade cobalt limonitic laterite ore to produce MHP and, in some cases, further refine the MHP to nickel sulfate and cobalt sulfate. First production from the most complete plant, being built by PT Halmahera Persada Lygend on Obi Island, was expected to begin by March 2021. Phase 1 of the Lygend plant was forecast to produce MHP containing 36,000 t/yr of nickel and 4,400 t/yr of cobalt. Other HPAL plants under construction included PT Adhikara Cipta Mulia's plant at Konawe, Southeast Sulawesi, PT Huayue Nickel Cobalt at Morowali, Central Sulawesi, PT QMB New Energy Materials's plant at Morowali, Central Sulawesi, and PT Smelter Nikel Indonesia in Banten on the island of Java (CNBC Indonesia, 2020; Thomson Reuters, 2020b, c).

Japan.—In 2020, Japan ranked fifth in terms of global production of refined cobalt. Sumitomo's Niihama nickel refinery in Ehime Prefecture processed MSP produced at plants in the Philippines owned by Sumitomo subsidiaries Coral Bay Nickel Corp. (Philippines) and Taganito HPAL Nickel Corp.

(Philippines), nickel matte from PT Vale in Indonesia, and additional nickel raw materials from elsewhere. The Niihama refinery produced cobalt chloride, most of which was converted to electrolytic cobalt (cathode) for sale (table 8; Sumitomo Metal Mining Co., Ltd., 2020, p. 52–54, 115; Cobalt Institute, 2021, p. 17; Darton Commodities Ltd., 2021, p. 92).

Sumitomo's Harima refinery in Hyogo Prefecture processed MSP 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 electrolytic cobalt (cathode). 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 (Sumitomo Metal Mining Co., Ltd., 2020, p. 54; Darton Commodities Ltd., 2021, p. 92).

Madagascar.—The Ambatovy joint venture (Sumitomo Corp. and Korea Resources Corp.), Madagascar's sole nickel-cobalt mining, processing, and refining operation, was placed on care-and-maintenance status in late March 2020 in response to national lockdown restrictions resulting from the COVID-19 pandemic. Operations did not restart by yearend 2020 and, as a result, cobalt production was estimated to have decreased significantly. In August, Sherritt completed a transaction that sold their 12% interest in Ambatovy and proceeded to withdraw from its role as the joint venture's operator (tables 7, 8; Ziswa, 2020; Sherritt International Corp., 2021, p. 8–9).

Mexico.—Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (MMB) (majority owned by Korea Resources Corp.) owned and operated the El Boleo project, which consisted of a copper-cobalt-zinc mine and refinery in Baja California Sur. In April, MMB temporarily suspended operations at the mine to minimize the spread of the virus during the COVID-19 pandemic. At yearend 2020, MMB's request from mid-2019 to extend the area available for surface mining had not been approved. The company stated that without the expansion, the mine would not be able to continue operations (Camrova Resources Inc., 2020; PeninsularDigital, 2021).

Morocco.—Compagnie de Tifnout Tighanimine (CTT) (a subsidiary of Groupe Managem) mined cobalt arsenide ores and produced crude cobalt hydroxide in Bou-Azzer. The hydroxide was refined to electrolytic cobalt (cathode) at CTT's Guemassa hydrometallurgical refinery north of Marrakech. In 2020, CTT produced 2,416 t of refined cobalt from mined and secondary (scrap) materials, despite a 3-week suspension at the Guemassa refinery in response to the COVID-19 pandemic. Mine production benefitted from the installation of a new gravity unit at the beneficiation plant, which improved metal recovery and concentrate quality (Groupe Managem, 2021, p. 21, 30, 104, 106).

New Caledonia.—In 2020, estimated recoverable mine production increased by 29% compared with that in 2019. Vale Nouvelle-Calédonie S.A.S. (VNC) [Vale and Société de Participation Minière du Sud Caledonien S.A.S. (SPMSC)] was New Caledonia's sole cobalt producer. In 2020, VNC produced 2,198 t (1,703 t in 2019) of cobalt as intermediate products from its mining and HPAL processing operation in the southern tip of New Caledonia's main island. In April, VNC decommissioned the operation's nickel refinery, after which it ceased production

of nickel oxide, nickel hydroxide, and crude cobalt carbonate and produced only MHP. In December, Vale entered an option agreement for the sale of its majority share in the operation to Prony Resources, a consortium of VNC management and employees and Trafigura; a few days later, operations were temporarily suspended following a protest at the site (table 7; Vale S.A., 2020b; 2021, p. 10, 57, 65).

Norway.—In 2020, Norway was the fourth-ranked global producer of refined cobalt. Glencore’s production of electrolytic cobalt (cathode) at Nikkelverk, Norway’s sole refinery, was essentially unchanged from that in 2019. The company’s Sudbury and Raglan operations in Canada supplied 14% of the cobalt refined at Nikkelverk; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies (table 8; Cobalt Institute, 2021, p. 17; Glencore plc, 2021, p. 50, 232; 2023).

Papua New Guinea.—In 2020, the Ramu nickel-cobalt joint venture between majority owner and operator Metallurgical Corporation of China Ltd. and Nickel 28 Capital Corp. produced essentially the same amount of cobalt in MHP as it did in 2019. MHP from the joint venture’s Kurumbukari nickel-cobalt laterite mine and Basamuk HPAL processing plant was exported to China to be refined (table 7; Darton Commodities Ltd., 2021, p. 12, 82; Nickel 28 Capital Corp., 2021, p. 4–5).

Philippines.—In 2020, the Philippines ranked fourth in global production of mined cobalt. Two HPAL processing plants produced MSP from lateritic ore mined in the Philippines—Coral Bay Nickel and Taganito. Coral Bay Nickel was a joint venture among Sumitomo, Mitsui & Co., Ltd. (Japan), Sojitz Corp. (Japan), and Nickel Asia 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, listed in order of share, with operations at Nickel Asia’s Taganito Mine in the northeastern region of Mindanao Island. The MSP was sent to Sumitomo’s Niihama and Harima refineries in Japan (table 7; Sumitomo Metal Mining Co., Ltd., 2020, p. 51, 54).

Russia.—In 2020, Russia ranked second in global cobalt mine production and eighth in production of refined cobalt. Nor Nickel was the main producer of mined cobalt in Russia and the sole producer of Russia’s refined cobalt. Production from the company’s Norilsk division took place on the Taymyr Peninsula, where it mined and beneficiated copper-nickel sulfide ores and smelted the concentrates. Production from its Kola division took place on the Kola Peninsula, where it mined and beneficiated nickel-copper sulfide ores and smelted the concentrates. Nor Nickel’s matte was refined by the Kola division at its Severonickel refinery at Monchegorsk on the Kola Peninsula and its Harjavalta refinery in Finland. The Severonickel refinery produced three grades of electrolytic cobalt (cathode) and crude cobalt hydroxide. In December, as part of Nor Nickel’s reconfiguration plan, the company shut down the smelter at Nikel on the Kola Peninsula (tables 7, 8; Khodov, 2019; PJSC MMC Norilsk Nickel, 2021, p. 16–17, 20, 90–94).

South Africa.—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Nor Nickel) produced 708 t of cobalt in nickel concentrate in 2020 (737 t in 2019). Concentrate from Nkomati was sold to Metal

Trade Overseas AG (African Rainbow Minerals Ltd., 2020, p. 65; 2021, p. 14).

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 of the United Kingdom) produced cobalt sulfate at its base-metals refinery near Rustenburg, North West Province. 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 (Impala Platinum Holdings Ltd., 2020; Anglo American Platinum Ltd., 2021, p. 117; Sibanye Stillwater Ltd., 2021, p. 90–91).

Two other platinum producers, Sibanye Stillwater and Northam Platinum Ltd., had base-metals refineries that processed materials containing nickel and cobalt. In 2020, Thakadu Battery Materials Pty. Ltd. was commissioning a plant at Sibanye Stillwater’s Marikana base-metals refinery to refine the operation’s crude nickel sulfate to battery-grade nickel sulfate and crude cobalt hydroxide (Northam Platinum Ltd., 2020, p. 21; Thakadu Group, 2021a, b).

Turkey.—Two companies recovered cobalt from ores mined in Turkey. Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. (jointly owned by Vestel Elektronik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) produced MHP containing 4,723 t of nickel metal equivalent and an estimated 250 t of cobalt from its HPAL processing plant at Gordes, Manisa Province. Production increased from the 2,175 t of nickel equivalent and an estimated 120 t of cobalt in 2019, owing to an increase in operating days at the plant, which used local nickel-cobalt lateritic ore as feed. The company planned investments to produce value-added nickel sulfate and cobalt carbonate products (Vestel Elektronik Sanayi ve Ticaret A.Ş., 2021, p. 115, 274).

Eti Bakir A.Ş. (Cengiz Holding A.Ş.) produced copper concentrate and cobalt-bearing pyrite concentrate from its Küre mining operation in Kastamonu Province. The company roasted the pyrite concentrate to produce sulfuric acid for its Mazıdaği phosphate plant in Mardin Province. The calcine generated by roasting the pyrite was then treated at the Mazıdaği plant using a hydrometallurgical process to recover cobalt as crude cobalt carbonate. In 2020, Eti Bakir ramped up production to an estimated 2,400 t of cobalt in carbonate from 500 t in 2019. Most of the crude carbonate was exported to China and Finland to be refined (Metso Outotec Corp., 2019; Darton Commodities Ltd., 2021, p. 10, 83; Eti Bakir A.Ş., undated).

Zambia.—According to the Zambian Ministry of Finance, in 2020, production of mined cobalt decreased by 17% from that in 2019. Chambishi Metals [owned by ERG and Government-owned ZCCM Investments Holdings Plc (ZCCM-IH)] was Zambia’s sole producer of refined cobalt. Chambishi Metals processed imported crude cobalt hydroxide from ERG’s Metalkol operation in Congo (Kinshasa) from mid-2019 until late January 2020. ERG placed the refinery on care-and-maintenance status because high impurity levels in the hydroxide feed led to inconsistent and poor-quality metal

production (table 7; Darton Commodities Ltd., 2021, p. 76; Ministry of Finance, 2021, p. 12).

Konkola Copper Mines Plc (KCM) [owned by Vedanta Resources Ltd. (India) and ZCCM–IH] processed concentrates from its Zambian copper mining operations and from other sources at its Nchanga copper smelter. The smelter had the capability to recover cobalt as an intermediate copper-iron-cobalt alloy. In 2019, 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 2020 (Darton Commodities Ltd., 2021, p. 10; ZCCM Investments Holdings Plc, 2021; Konkola Copper Mines Plc, undated).

Mabiza Resources Ltd., a subsidiary of Consolidated Nickel Mines Ltd. (CNM) (United Kingdom), produced nickel concentrate at the Munali nickel sulfide mine in southern Zambia. The concentrate contained 2,760 t of nickel and an estimated 160 t of cobalt, based on average concentrate grades of 12.3% nickel and 0.7% cobalt (Consolidated Nickel Mines Ltd., 2022).

In 2019, Jubilee Metals Group PLC (United Kingdom) acquired Sable Zinc Kabwe Ltd., owner of a metal refinery in Kabwe, from Glencore. By mid-2020 Jubilee had commissioned the refinery's copper and cobalt circuits and was securing the rights to process copper-cobalt tailings from other companies operating in Zambia. Jubilee planned to build three beneficiation plants to upgrade the tailings to concentrates, which would be refined to copper cathode and an intermediate cobalt product at the Sable refinery (Jubilee Metals Group PLC, 2020, p. 10, 14–16; 2021, p. 10).

Zimbabwe.—Bindura Nickel Corporation Ltd., Mimosa Mining Co. (jointly owned by Implats and Sibanye Stillwater), and Zimplats Holdings Ltd. generated small quantities of byproduct cobalt from their nickel and platinum mining operations.

Outlook

Historically, trends in refined cobalt consumption generally followed those of global industrial production. Increases in cobalt consumption by the rechargeable battery industry, initially for personal electronics and increasingly for electric vehicles and energy storage systems, have resulted in annual growth rates for global cobalt consumption exceeding growth rates for the global gross domestic product (Taarland, 2009, p. 7; Darton Commodities Ltd., 2021, p. 37–39; Cobalt Institute, 2022, p. 40).

Several industry analysts forecast that global cobalt mine and intermediate production will increase significantly in the near to medium term, 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. Between 2020 and 2025, cobalt supply is forecast to increase by 10% to 11% and consumption is forecast to increase by 12% to 13%. It has been noted that without investment in additional mine projects, a deficit between cobalt supply and consumption will develop or increase from 2024 onwards (Darton Commodities Ltd., 2021, p. 23, 37, 65–66; Fisher, 2021, p. 13, 16; Cobalt Institute, 2022, p. 40–42).

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TABLE 1
SALIENT COBALT STATISTICS¹

(Metric tons, cobalt content, unless otherwise specified)

	2016	2017	2018	2019	2020	
United States:						
Mine production ^e	690	640	480	500	600	
Consumption:						
Estimated ²	9,010	9,240	9,290	9,050	7,260	
Apparent ^{2,3}	11,500	8,950	7,680 ^r	12,500	8,470	
Imports for consumption	12,800	11,900	11,900	13,900	9,740	
Exports	4,160	5,690	6,980 ^r	4,080 ^r	3,440	
Stocks, December 31:						
Industry ^{e,2,4}	969	1,020	1,060	1,090	952	
London Metal Exchange Ltd. (LME), U.S. warehouses	195	160	130	102	82	
U.S. Government: ⁵						
Metal	301	302	302	302	302	
Lithium-cobalt oxide	gross weight	(6)	1	1	1	
Lithium-nickel-cobalt-aluminum oxide	do.	1	2	2	3	
Cobalt alloys	do.	--	(6)	3	11	
Price, metal:						
U.S. spot ⁷	dollars per pound	12.01	26.97	37.43	16.95	15.70
LME, cash ⁸	do.	11.57	25.28	32.94	14.88	14.21
World:						
Production: ⁹						
Mine	115,000 ^r	128,000 ^r	149,000 ^r	153,000 ^r	142,000	
Refinery	96,700	119,000 ^r	126,000 ^r	134,000 ^r	130,000	
Stocks, December 31, LME ¹⁰	691	580	863	685	451	

^eEstimated. ^rRevised. do. Ditto. -- Zero.

¹Table includes data available through November 15, 2021. Data are rounded to no more than three significant digits, except prices.

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

³Defined as imports minus exports plus adjustments for Government and industry stock changes plus secondary production, as estimated from consumption of purchased scrap.

⁴Stocks held by cobalt processors and consumers.

⁵Source: Defense Logistics Agency Strategic Materials.

⁶Less than ½ unit.

⁷Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by S&P Global Platts Metals Week.

⁸Annual 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.

⁹May include estimated data.

¹⁰Stocks held in Asia, Europe, and the United States.

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

(Metric tons, cobalt content)

	2019	2020
Consumption by end use:		
Steels and other alloys, excludes superalloys ³	1,230	1,180
Superalloys	4,220	3,020
Cemented carbides ⁴	799	629
Chemical and ceramic uses	2,800	2,420
Total	9,050	7,260
Consumption by form:		
Chemical compounds, organic and inorganic ⁵	2,150	2,140
Metal	4,150	3,100
Purchased scrap	2,750	2,010
Total	9,050	7,260
Stocks, December 31: ⁶		
Chemical compounds, organic and inorganic ⁵	488	387
Metal	W	W
Purchased scrap	W	W
Total	1,090	952

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

¹Table includes data available through November 15, 2021. 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 magnetic alloys, nonferrous alloys, wear- and corrosion-resistant alloys, welding materials, and other metallic uses not listed.

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

⁵Includes oxides.

⁶Stocks held by cobalt processors and consumers.

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

Form	HTS ² codes	2019			2020		
		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	11,900	11,900	\$453,000	8,140	8,140	\$282,000
Oxides and hydroxides	2822.00.0000	1,710	1,230	44,300	1,260	910	30,600
Other:							
Acetates	2915.29.3000	97	23	1,110	171	41	1,550
Carbonates	2836.99.1000	729	335	16,400	702	323	12,600
Chlorides	2827.39.6000	128	32	1,500	81	20	795
Sulfates	2833.29.1000	1,150	312	8,840	1,120	303	8,600
Total		15,800	13,900	525,000	11,500	9,740	336,000

¹Table includes data available through July 29, 2021. 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)	Cobalt content ⁵	Quantity (metric tons)		Value ⁶ (thousands)	Cobalt content ⁵	Quantity (metric tons)		Value ⁶ (thousands)	Cobalt content ⁵	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	Gross weight		Cobalt content ⁵		
2019:															
Australia	725	725	\$33,700	--	--	--	--	--	--	--	--	725	725	\$33,700	
Belgium	59	59	2,640	561	404	\$15,700	33	9	186	57	1,570	653	472	18,500	
Brazil	20	20	710	--	--	--	3	1	3	1	57	206	77	2,280	
Canada	2,400	2,400	88,000	--	--	--	163	46	3	1	57	2,400	2,400	88,100	
China	213	213	10,500	221	159	5,650	131	39	131	39	1,310	598	418	18,200	
Finland	471	471	18,300	293	211	7,770	1,470	507	1,470	507	20,900	2,230	1,190	46,900	
Germany	49	49	2,470	--	--	--	21	9	21	9	692	69	58	3,160	
Japan	1,400	1,400	52,500 ^r	1	1	23	3	1	3	1	33	1,400 ^r	1,400	52,600 ^r	
Korea, Republic of	(7)	(7)	20	147	106	2,100	(7)	(7)	(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)	(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	6	2	17	1,220	1,220	42,200	
South Africa	307	307	2,570	--	--	--	--	--	--	--	--	307	307	2,570	
Taiwan	1	1	54 ^r	74	54	1,970	6	1	6	1	67	82	56	2,090	
United Kingdom	39	39	1,450	411	296	11,200	164	52	164	52	1,940	614	386	14,500	
Other	11	11	730	(7)	(7)	7	56	17	56	17	424	67	28	1,160	
Total	11,900	11,900	453,000	1,710	1,230	44,300	2,110	702	2,110	702	27,900	15,800	13,900	525,000	
2020:															
Australia	722	722	23,900	20	15	351	--	--	--	--	--	742	737	24,200	
Belgium	6	6	217	275	198	7,560	16	7	211	70	285	296	210	8,060	
Brazil	--	--	--	--	--	--	211	70	211	70	2,410	211	70	2,410	
Canada	1,950	1,950	61,100	(7)	(7)	4	1	1	4	1	12	1,950	1,950	61,100	
China	33	33	862	48	34	949	131	39	131	39	1,310	212	107	3,120	
Finland	325	325	11,600	388	280	9,420	1,500	511	1,500	511	17,400	2,210	1,120	38,400	
Germany	56	56	3,000	2	1	51	3	1	3	1	22	61	58	3,070	
Japan	1,340	1,340	47,000	--	--	--	10	2	10	2	56	1,350	1,350	47,000	
Korea, Republic of	(7)	(7)	5	41	29	918	--	--	--	--	--	41	29	923	
Madagascar	397	397	14,000	--	--	--	--	--	--	--	--	397	397	14,000	
Mexico	61	61	1,940	1	1	20	1	(7)	1	(7)	12	63	62	1,970	
Morocco	356	356	11,000	--	--	--	--	--	--	--	--	356	356	11,000	
Norway	1,910	1,910	79,300	--	--	--	--	--	--	--	--	1,910	1,910	79,300	
Russia	713	713	23,600	--	--	--	--	--	--	--	--	713	713	23,600	
South Africa	205	205	1,620	--	--	--	--	--	--	--	--	205	205	1,620	
Taiwan	--	--	--	58	42	1,080	72	19	72	19	615	129	61	1,700	
United Kingdom	52	52	2,550	406	292	9,650	131	35	131	35	1,370	589	380	13,600	
Other	9	9	579	26	19	569	3	1	3	1	73	38	29	1,220	
Total	8,140	8,140	282,000	1,260	910	30,600	2,070	687	2,070	687	23,500	11,500	9,740	336,000	

See footnotes at end of table.

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

¹Revised. -- Zero.
²Table includes data available through July 29, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
³United States (HTS) codes 8105.20.6000 and 8105.20.9000.
⁴HTS code 2822.00.0000.
⁵Cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates under HTS codes 2827.39.1000, 2833.29.1000, 2836.99.1000, and 2915.29.3000.
⁶Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; carbonates, 46%; chlorides, 25%; and sulfates, 27%.
⁷Customs value.
⁸Less than 1/2 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)
2019	3,980 r	\$128,000	79	\$1,710	203	\$2,360	(9)	\$9	4,080 r	\$132,000
2020:										
Belgium	45	1,960	--	--	235	1,010	--	--	101	2,970
Brazil	84	3,170	--	--	--	--	--	--	84	3,170
Canada	944	7,670	63	2,320	--	--	--	--	989	9,990
China	68	3,810	1	36	--	--	--	--	69	3,840
France	272	7,290	(9)	4	--	--	--	--	272	7,300
Germany	381	16,600	(9)	13	--	--	(9)	3	382	16,600
Hong Kong	6	504	--	--	--	--	--	--	6	504
Hungary	4	777	--	--	--	--	--	--	4	777
India	41	1,720	1	11	98	2,430	--	--	65	4,160
Ireland	631	21,700	--	--	--	--	--	--	631	21,700
Italy	19	2,020	(9)	16	--	--	--	--	20	2,040
Japan	132	6,050	(9)	8	--	--	--	--	132	6,060
Korea, Republic of	73	3,320	3	18	--	--	--	--	76	3,340
Luxembourg	40	1,190	--	--	--	--	--	--	40	1,190
Mexico	6	867	6	164	39	338	1	14	19	1,380
Netherlands	38	1,160	--	--	--	--	2	36	39	1,200
Russia	7	371	--	--	--	--	--	--	7	371
Saudi Arabia	4	360	--	--	--	--	--	--	4	360
Singapore	33	3,000	--	--	--	--	--	--	33	3,000
Switzerland	30	1,110	--	--	--	--	--	--	30	1,110
Taiwan	36	1,120	(9)	3	--	--	--	--	36	1,120
Tunisia	89	1,700	--	--	--	--	--	--	89	1,700
Turkey	27	783	--	--	--	--	--	--	27	783
United Kingdom	262	7,000	--	--	--	--	--	--	262	7,000
Other	23	2,520	1	45	1	3	--	--	24	2,570
Total	3,300	97,700	74	2,630	372	3,780	3	52	3,440	104,000

¹Revised. -- Zero.

²Table includes data available through July 29, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

³In addition to the materials listed, the United States exported cobalt ores and concentrates and wrought cobalt and cobalt articles.

⁴Includes 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.

⁵Schedule B code 2822.00.0000.

⁶Schedule B code 2915.29.3000.

⁷Schedule B code 2827.39.6000.

⁸Free alongside ship value.

⁹Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; and chlorides, 25%.

¹⁰Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 6
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2020^{1,2}

(Metric tons, cobalt content)

Country or locality	Capacity
Australia	6,900 ^e
Belgium	3,000 ^e
Brazil	2,000
Canada	8,020
China	166,000
Congo (Kinshasa)	6,050 ^e
Finland	16,500
France	400
India ³	1,000 ^e
Japan	5,500 ^e
Madagascar	5,600
Mexico	1,700
Morocco	2,800
Norway	5,200
Russia ⁴	3,000
South Africa	3,000 ^e
Turkey	2,100
Uganda	720
Zambia	9,600
Total	249,000 ^e

^eEstimated.

¹Table includes data available through August 4, 2021. 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.

³Capacity reduced from that of previous year; represents only Nicomet Industries Ltd.

⁴Capacity reduced from that of previous year; represents only Kola MMC (PJSC MMC Norilsk Nickel subsidiary).

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

(Metric tons, cobalt content)

Country or locality ³	2016	2017	2018	2019	2020
Australia ⁴	5,140	5,034	4,878	5,746 ^r	5,632
Botswana ⁵	248	--	--	--	--
Brazil	852	185	-- ^e	30 ^e	160 ^e
Canada ⁶	4,216	3,704	3,279	3,956 ^r	3,693
China	2,300 ^e	2,500 ^e	2,000 ^e	2,241 ^r	2,200 ^e
Congo (Kinshasa) ^{e,7}	68,000	80,000	104,000	107,000 ^r	98,000
Cuba ^{e,8}	3,900	3,900	3,500	3,800	3,800
Finland ⁹	690 ^e	1,000 ^e	1,377	1,454	1,559
Indonesia ^{e,10}	1,200	1,200	1,200	1,100	1,100
Madagascar ^{e,11}	3,800	3,600	3,300	3,400	850
Mexico ^e	980	1,000	1,400	1,100	1,000
Morocco ^{e,12}	1,600	2,300	2,300	2,300	2,300
New Caledonia ^{e,13}	3,390	2,780	2,100	1,700	2,200
Papua New Guinea ¹⁴	2,191	3,308	3,275	2,911	2,941
Philippines ^{e,15}	4,000	3,800 ^r	3,600 ^r	3,900 ^r	4,500
Russia ¹⁶	8,600 ^r	8,900 ^r	8,700 ^r	8,700 ^r	9,000 ^e
South Africa ^e	2,300	2,300	2,300	2,100	1,800
Turkey ¹⁴	100 ^e	220	259	120 ^e	250 ^e
United States ^{e,16}	690	640	480	500	600
Vietnam ¹⁶	134	--	--	--	--
Zambia	600 ^e	990	835	379 ^r	316
Zimbabwe	409	445	403	400 ^e	350 ^e
Total	115,000 ^r	128,000 ^r	149,000 ^r	153,000 ^r	142,000

^eEstimated. ^rRevised. -- Zero.

¹Table includes data available through September 23, 2021. 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 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.

⁵Reported cobalt content of pelletized nickel-copper matte.

⁶Data for 2016–19 are recoverable cobalt in concentrates shipped reported by Natural Resources Canada. Data for 2020 are recoverable cobalt production reported by Statistics Canada.

⁷Determined 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.

⁸Determined from estimated cobalt content of nickel-cobalt sulfide production and estimated cobalt content of ammoniacal liquor production.

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

¹⁰Estimated cobalt content of nickel matte plus estimated cobalt in lateritic ore processed in Australia.

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

¹²Cobalt content of concentrate estimated from reported or estimated gross weight.

¹³Cobalt 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.

¹⁴Cobalt content of nickel-cobalt hydroxide.

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

¹⁶Cobalt content of concentrates.

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

(Metric tons, cobalt content)

Country or locality and form	2016	2017	2018	2019	2020
Australia, metal powder and oxide hydroxide ³	3,350 ^{e,4}	3,000	3,200	3,700 ⁵	3,300 ⁵
Belgium, metal powder, oxide, hydroxide ^{e,6}	1,500	1,600	1,650	1,500	1,300
Brazil, metal ³	400	46	8	--	--
Canada, metal, metal powder, oxide	6,302	6,355	6,349 ⁷	6,075 ⁷	5,965 ⁷
China, metal, metal powder, oxide, salts ^e	49,900	75,000	83,100	90,000	90,000
Congo (Kinshasa), metal ⁸	50	120	60	-- ^e	-- ^e
Finland, metal powder and salts ⁹	12,393	13,585 ^r	14,295 ^r	14,283 ^r	15,148
France, chloride ³	119	277	48	90 ^e	90 ^e
India, metal and salts ³	100	100	100	NA	NA
Japan, metal ³	4,305	4,159	3,669	3,800 ^e	4,000 ^e
Madagascar, metal powder	3,273	3,053	2,852	2,900	700 ^e
Mexico, metal	419	420 ^e	226	215	190 ^e
Morocco, metal	2,081	1,924	1,806	2,397	2,416
Norway, metal	3,541	3,473	4,166	4,354	4,400
Russia, metal ³	3,092	2,077	1,800	2,000 ^e	1,800 ⁶
South Africa, metal powder and sulfate ³	1,101	1,062	1,089	1,000 ^e	800 ^e
Zambia, metal ³	4,725	2,520	1,613	1,500 ¹⁰	-- ^e
Total	96,700	119,000 ^r	126,000 ^r	134,000 ^r	130,000

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

¹Table includes data available through September 23, 2021. 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: Cobalt Institute (formerly Cobalt Development Institute), except as noted.

⁴Includes estimated production by Queensland Nickel Pty. Ltd. reported by Darton Commodities Ltd.

⁵Source: Glencore plc.

⁶Source: Darton Commodities Ltd.

⁷Excludes cobalt oxide.

⁸Does not include production of cobalt in alloys, carbonate, hydroxide, and other materials that would require further refining.

⁹Source: Geological Survey of Finland.

¹⁰Source: Eurasian Resources Group.