



2016 Minerals Yearbook

COBALT [ADVANCE RELEASE]

COBALT

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In 2016, world production of refined cobalt decreased by 3% to 96,600 metric tons (t) (table 9). The decrease was a result of lower production in China and suspension of production at Kamoto Copper Company SA in Congo (Kinshasa), at the Palmer Nickel and Cobalt Refinery in Australia, and at Votorantim Metais S.A. in Brazil. The United States did not refine cobalt in 2016. World cobalt mine production decreased by 6% to 113,000 t (table 8). Congo (Kinshasa) remained the leading producer of mined cobalt, supplying more than one-half of world production, followed by Australia and Russia, Cuba, and Canada. Cobalt was mined in the United States as a byproduct of nickel and copper in Michigan, and a negligible amount of byproduct cobalt was produced in an intermediate product from the mining and refining of platinum-group-metals (PGM) ore in Montana. No cobalt has been sold from the National Defense Stockpile (NDS) since 2009.

According to the Cobalt Development Institute (2017), preliminary data indicated that in 2016, world apparent consumption of cobalt decreased by about 2,000 t from that of 2015 to approximately 85,000 t. An increase in purchases of cobalt metal by nonconsuming entities, such as China's State Reserve Bureau, metal traders, and investment funds, removed cobalt from the market in 2016. As a result, in 2016, the cobalt market shifted from surplus to deficit. In late 2015, cobalt prices were the lowest since 2003. During 2016, prices generally trended upward, although annual averages were less than those of 2015. Rising prices, forecasts of increasing demand for cobalt in electric vehicles, and anticipation of potential future supply deficits led junior mining companies to increase their acquisitions of prospective cobalt properties worldwide. Of particular interest were properties where cobalt would be produced as a principal product, such as those in Idaho and the former silver-cobalt mining area near Cobalt, Ontario, Canada. At the other end of the cobalt supply chain, battery and electric vehicle manufacturers showed an increasing interest in establishing multiyear cobalt contracts to meet their anticipated future raw material needs (Darton Commodities Ltd., 2017, p. 23, 38–39, 52; Spencer, 2017, p. 9). Salient U.S. and world cobalt statistics for 2012–16 are listed in table 1.

Cobalt is a metal used in numerous diverse commercial, industrial, and military applications. Globally, the leading use of cobalt is in rechargeable battery electrodes. Superalloys, which are used to make parts for gas turbine engines, are another major use for cobalt. Other metallurgical uses for cobalt include 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 include animal feed additives; catalysts for chemical, petroleum, and other 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 vitamin B12.

Legislation and Government Programs

Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt during 2016. The program under which cobalt metal sales were authorized expired in 2011 and had not been reauthorized. DLA Strategic Materials had a contract with a domestic producer to supply the agency with cobalt-bearing lithium-ion battery precursor materials. During the calendar year, DLA Strategic Materials purchased 209 kilograms (kg), gross weight, of lithium-cobalt oxide (LCO) and 460 kg, gross weight, of lithium-nickel-cobalt-aluminum oxide (NCA). The Annual Materials Plan for fiscal year 2017 (October 1, 2016, through September 30, 2017), which represented the maximum amounts of materials that could be bought or sold during the year, provided for acquisitions of 600 kg, gross weight, of LCO and 2,160 kg, gross weight, of NCA. Calendar yearend NDS inventories of cobalt materials are listed in table 1. The cobalt content of battery precursor material inventories was estimated as 60% of gross weight for LCO and 9% of gross weight for NCA (Defense Logistics Agency Strategic Materials, 2016; U.S. Department of Defense, 2017, p. 10).

Production

Lundin Mining Corp. (Toronto, Ontario, Canada) produced copper and nickel concentrates from the Eagle nickel-copper mine northwest of Marquette, MI, and the mill in Humboldt Township. In 2016, Eagle produced nickel concentrate containing 24,114 t of nickel and an estimated 690 t of cobalt, based on reported quarterly nickel production and ore grades and a forecast of annual cobalt ore grade from the production schedule (27,167 t of nickel and 760 t of cobalt in 2015). The decrease in nickel and estimated cobalt production was attributed to planned lower grades of ore fed to the mill in 2016. The concentrate was sent by rail to smelters in North America or to ports for shipment overseas (Lundin Mining Corp., 2017a, p. 24; 2017b, p. 18).

Stillwater Mining Co.'s PGM mining and refining operations in southeastern Montana produced negligible amounts of cobalt in nickel sulfate, which was sold to other companies. In December, Sibanye Gold Ltd. (Westonaria, South Africa) announced that it planned to acquire Stillwater Mining (Stillwater Mining Co., 2017, p. 7–8, 21).

In early 2016, the Minnesota Department of Natural Resources determined that the final environmental impact statement for PolyMet Mining Corp.'s NorthMet

copper-nickel-cobalt project met the requirements under the Minnesota Environmental Policy Act. PolyMet proceeded to apply for the permits required to construct and operate the project and had discussions with financial institutions regarding construction finance. Phase 1 of the project consisted of open pit mining of the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota and production of copper and nickel concentrates at PolyMet's Erie plant approximately 10 kilometers (km) west of the ore body. PolyMet expected construction and rampup to commercial production to take about 24 months after receiving the permits (table 7) (PolyMet Mining Corp., 2017, p. 3–4, 8, 15).

eCobalt Solutions Inc. (formerly named Formation Metals Inc.) commissioned a definitive feasibility study on its Idaho Cobalt project. The environmentally permitted project consisted of an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County and a hydrometallurgical plant to refine the concentrates in southern Idaho. Based on a 2015 preliminary economic analysis, the project would produce an average of approximately 1,260 metric tons per year (t/yr) of cobalt in sulfate for the battery sector during a 12.5-year mine life. The company planned to complete the feasibility study, secure offtake agreements, and arrange financing to develop the project. Once financing was completed, eCobalt planned to begin underground mine development and to construct the beneficiation and hydrometallurgical plants. Initial production was expected to take place about 13 months after completion of financing, with full production 8 months later (table 7) (eCobalt Solutions Inc., 2017a, p. 25–26; 2017b, p. 1, 3–4, 7).

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 table 2.

Cobalt was recovered from secondary (scrap) materials by subsidiaries of Umicore N.V./S.A. (Brussels, Belgium) and Plansee Group (Reutte, Austria). The Umicore Specialty Materials Recycling plant in Wickliffe, OH, processed secondary materials such as superalloy scrap and made chemicals for the catalyst and petrochemical refining industries. The Umicore Specialty Chemicals plant in Arab, AL, recycled spent catalysts for its customers. Plansee Group's Global Tungsten & Powders Corp. (GTP) in Towanda, PA, recovered an intermediate cobalt chemical compound as a byproduct of tungsten recovery from cemented carbide scrap. GTP had a partnership 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., undated).

Consumption

U.S. reported consumption of cobalt in 2016 was slightly more than that of 2015. Metallurgical and chemical industries each used slightly more cobalt than they did in 2015. 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, more than 50 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 2 include estimates to account for nonrespondents.

U.S. apparent consumption for 2016, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 12% more than that in 2015 (table 1). The increase was primarily a result of higher net imports in 2016.

Prices

The annual average U.S. spot price for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, was 11% less than that of 2015 (table 1). The overall price trend was upward, however. In mid-January, the price increased slightly; it remained stable through mid-July and then gradually trended upward during the remainder of the year. The lowest price range was in the first week of January, at \$9.50 to \$10.50 per pound, and the highest price range was \$15.00 to \$15.70 per pound during the last 3 weeks of the year.

Trends in Platts' prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were similar to those for United States spot cathode. The annual average of weekly prices for Zambian cobalt was \$11.93 per pound, and the annual average of weekly prices for Russian cobalt was \$11.91 per pound.

Expectations of potential future cobalt supply shortfalls and higher prices increased the interest in cobalt by hedge funds and other investors. Darton Commodities Ltd. (2017, p. 52) estimated that at least 1,000 t of cobalt metal was acquired for investment purposes in 2016.

At yearend, cobalt from 15 producers was approved for delivery on the London Metal Exchange Ltd. (LME) cobalt futures contract and the deliverable shapes of the approved brands were cathodes, ingots, rounds, and coarse-grain metal powder. Sherritt International Corp. (2017a, p. 10) reported that the amount of cobalt traded on the LME in 2016 (7,894 t) represented only 21.6% of global refined cobalt metal production and 8.6% of global refined production of cobalt metal and chemicals. Considering that base-metal contracts on the LME experience trading volumes of 50 or more times their production, the LME cobalt contract is still in the early stage of acceptance and remains a secondary pricing mechanism. The annual average mean of cash buyer and cash seller prices and yearend LME inventory levels are listed in table 1 (London Metal Exchange Ltd., The, undated).

Foreign Trade

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic production to meet U.S. 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 2016, net import reliance as a percentage of apparent consumption was 76%. Because U.S. cobalt mine production was exported to be refined, this indicates that 76% of U.S. cobalt supply was from imports and stock releases of refined cobalt and 24% was from domestic or imported scrap.

In 2016, the United States imported 12,800 t of cobalt contained in metal and chemical compounds, valued at \$327 million, 13% more than the 11,400 t imported in 2016 (tables 3, 4). On the basis of cobalt content, 11 countries supplied 93% of U.S. imports. Norway was the leading supplier, followed by Japan, Canada, Madagascar, Zambia, Finland, China, Russia, Australia, the United Kingdom, and Belgium. The United States also imported cobalt waste and scrap (1,030 t, gross weight, valued at \$13.8 million), unwrought cobalt alloys (820 t, gross weight, valued at \$27.0 million), and wrought cobalt and cobalt articles (167 t, gross weight, valued at \$21.9 million).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 4,160 t, valued at \$81.1 million, 9% more by weight than the 3,830 t exported in 2015. As listed in table 5, on the basis of cobalt content, the leading destinations for these exports were Canada, Ireland, France, the United Kingdom, Germany, Netherlands, and Belgium. The United States also exported 1,390 t, gross weight, of wrought metal and cobalt articles valued at \$96.5 million.

World Review

World cobalt mine and refinery production each decreased in 2016 compared with production in 2015. Cobalt mine production decreased in most countries, regardless of whether it was mined as a byproduct of copper or nickel. With regard to refinery production, significant increases in production in Canada, Finland, Mexico, Norway, Russia, and Zambia, were outweighed by decreases in production in Australia, Brazil, China, and Congo (Kinshasa).

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 the mine and refinery production of Morocco, the artisanal mining of the mineral heterogenite in Congo (Kinshasa), and the recovery of cobalt from previously stockpiled intermediate materials [for example, slags in Congo (Kinshasa)], which were processed primarily to recover cobalt.

In January, Amnesty International released a report that brought attention to the working conditions associated with artisanal mining in Congo (Kinshasa). The report highlighted health and safety hazards, child workers as young as 7 years in age, and the extortion of illegal payments from the miners by Government and security officials. It also emphasized the growing market for consumer electronics as a driving force for an increase in cobalt mining (Amnesty International, 2016, p. 4–8). This prompted producing and consuming companies throughout the cobalt supply chain (from mining companies to end users, such as manufacturers of consumer electronics and vehicles) to focus more attention on the sources of their cobalt-containing raw materials and components with regard to ethical and sustainable production. As a result, a number of initiatives

have been established to promote responsible working practices (Amoruso, 2017).

Refinery capacity by country is listed in table 6. The table does not include plants that processed refined cobalt, plants that used secondary materials (scrap) as their main source of feed, or plants that produced a cobalt product that required further refining.

The following review by country focuses on operations that produced cobalt in 2016. Expansions to those operations, operation restarts, and greenfield projects that were forecast to begin producing between 2017 and 2021 are listed in table 7.

Australia.—In 2016, estimated cobalt mine production from Western Australia, where cobalt is a byproduct of nickel mining and Australian production of refined cobalt, which included production from imported nickel laterite ore, each decreased (tables 8, 9).

The Palmer Nickel and Cobalt Refinery (owned by Australian businessman Clive Palmer, operated by Queensland Nickel Pty. Ltd.) in Townsville, Queensland, produced an estimated 150 t of refined cobalt as cobalt oxide hydroxide, a significant decrease from the 1,850 t produced in 2015. In mid-January 2016, Queensland Nickel entered voluntary administration as a result of financial problems owing to the low nickel price. The refinery ceased operations at the end of February owing to a shortage of feed-material supply and in late April, creditors voted to liquidate the company. In recent years, the refinery's main feed materials were lateritic ore imported from New Caledonia and the Philippines, intermediate nickel-cobalt hydroxide from the Ramu Nickel joint venture in Papua New Guinea, and an intermediate cobalt compound from Vale S.A.'s New Caledonia operation [FTI Consulting (Australia) Pty. Ltd., 2016, p. 4, 10, 13; Cobalt Development Institute, 2017; Darton Commodities Ltd., 2017, p. 7, 19].

BHP Billiton Plc's Nickel West operations in Western Australia consisted of open pit and underground nickel sulfide mines; concentrators, which processed ores mined by BHP Billiton and other companies; the Kalgoorlie smelter, where nickel matte was produced from domestic and imported nickel concentrates; and the Kwinana nickel refinery, which produced cobalt in intermediate nickel-cobalt sulfide. In 2016, nickel production from the refinery increased as a result of debottlenecking the operations (BHP Billiton Plc, 2016, p. 234–235; 2017, p. 9; Ingram, 2016).

Minara Resources Ltd. (Glencore plc) produced 3,200 t of cobalt metal at its Murrin Murrin nickel-cobalt laterite mining and pressure-acid-leaching operation in Western Australia (3,300 t in 2015). The decrease in production was the result of a decrease in cobalt recovered from third-party feed. Approximately 400 t of Murrin Murrin's 2016 production was from third-party feed, compared with 500 t in 2015 (Glencore plc, 2017, p. 210).

First Quantum Minerals Ltd. (Vancouver, British Columbia, Canada) produced intermediate nickel-cobalt hydroxide from its Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant in Western Australia. In 2016, the plant produced 23,624 t of nickel and, based on the hydroxide containing 40% nickel and 1.4% cobalt, an estimated 830 t of

cobalt (26,668 t of nickel and an estimated 930 t of cobalt in 2015). The decrease in production was attributed to maintenance and repairs to the high-pressure acid leaching circuits in the plant throughout the year. In 2015, it was reported that most of Ravensthorpe's hydroxide was sent to China, with lesser amounts sold to Brazil and India (Metal Bulletin Daily, 2015; First Quantum Minerals Ltd., 2017, p. 12).

Independence Group NL completed construction of its Nova underground nickel-copper-cobalt sulfide mine east of Norseman, Western Australia; commissioned the beneficiation plant; and began production and shipment of nickel and copper concentrates by yearend. Independence planned to ramp up to full production by mid-2017, at which time output was expected to include 900 to 1,000 t/yr of cobalt in nickel concentrate. For the first 3 years of operation, the nickel concentrate was to be sold to BHP Billiton's Nickel West operation and Glencore (Independence Group NL, 2016, p. 18; 2017, p. 13, 15).

In late May, Panoramic Resources Ltd. placed its Savannah underground nickel-copper sulfide mine operation in Western Australia on care-and-maintenance status to preserve the resource until nickel prices improved. Before then, the mine produced concentrates containing 235 t of cobalt (465 t in 2015), which were shipped to Jinchuan Group Co. Ltd.'s operations in China under a long-term offtake agreement (Panoramic Resources Ltd., 2016, p. 3).

In February, in response to low nickel prices, Mincor Resources NL ceased production of nickel-copper sulfide ore from its Mariners and Miitel Mines in Western Australia and placed the mines on care-and-maintenance status. Prior to shutdown, all the ore was toll processed by BHP Billiton at its Nickel West Kambalda concentrator and the resulting concentrate was sold to BHP Billiton under long-term agreements (Mincor Resources NL, 2016, p. 10).

Belgium.—According to the Cobalt Development Institute (2017), Umicore's 2016 cobalt refinery production was 6,329 t of contained cobalt, essentially unchanged from the 6,306 t produced in 2015. Umicore converted various cobalt materials into a wide range of chemicals and metal powders at refineries in Olen, Belgium, and Ganzhou, Jiangxi Province, China. Feed for the Olen refinery included cobalt recovered by Umicore's recycling operation in Hoboken and crude cobalt hydroxide from the Tenke Fungurume operation in Congo (Kinshasa). In 2016, Umicore began construction to upgrade its cobalt refining facility at Olen. The upgrade was expected to increase the company's ability to recycle cobalt and nickel-bearing residues. The company also had cobalt-processing plants, which made specialty chemicals or metal powders from refined cobalt or scrap, in Arab, AL, LaVergne, TN, and Wickliffe, OH; Bruges, Belgium; Fort Saskatchewan, Alberta, Canada; Jiangmen, Guangdong Province, China; and Cheonan, Republic of Korea (Umicore N.V./S.A., 2016, p. 7; undated; Darton Commodities Ltd., 2017, p. 14, 24).

Botswana.—Bamangwato Concessions Ltd.'s (BCL's) financial situation worsened as a result of low copper and nickel prices; below target mine production in 2015 at Selebi-Phikwe, owing to under-capitalization of mine infrastructure and equipment; and a loss of revenue and production when a shutdown to modernize the smelter in 2015 lasted longer than

planned. In 2016, BCL continued to seek funding to clear debts and invest in production, but by early October, the Government of Botswana, BCL's 100% shareholder, appointed a provisional liquidator for the company. BCL's mining operations, including Tati Nickel Mining Co. Pty. Ltd., were placed on care-and-maintenance status and the smelter was shut down (eNews Channel Africa, 2016; Lebanna, 2016).

Brazil.—In early 2016, in response to a decrease in nickel prices, Votorantim Metais S.A. suspended its nickel-cobalt laterite mining operation in Niquelandia, Goias State, and refined nickel and cobalt production at Sao Miguel Paulista, Sao Paulo State. Votorantim planned to keep the operations on care-and-maintenance status until market conditions improved (Votorantim S.A., 2016, p. 17).

Mirabela Nickel Ltd. was placed under voluntary administration in September 2015, and in early 2016, the company's Santa Rita open pit nickel sulfide mine and concentrator in Bahia State were placed on care-and-maintenance status. In June, the receivers and managers announced that no acceptable offers for Mirabela Nickel's assets had been found, so the company was placed in liquidation [Mirabela Nickel Ltd. (in liquidation, receivers and managers appointed), 2016].

Canada.—Vale's global cobalt production was 5,799 t in 2016, 28% more than the 4,533 t produced in 2015. Vale produced 1,851 t (1,448 t in 2015) of refined cobalt metal at its Port Colborne, Ontario, refinery; 3,188 t (2,926 t in 2015) of cobalt in a cobalt intermediate product at its nickel operations in Canada and New Caledonia; and 761 t (159 t in 2015) of cobalt contained in other intermediate products such as nickel concentrates. Vale's cobalt originated from company-owned nickel sulfide mines at Sudbury, Ontario, Thompson, Manitoba, and Voisey's Bay in northeastern Labrador; from company-owned nickel laterite mines in Indonesia and New Caledonia; and from purchased feedstock materials. Vale reported that 882 t (751 t in 2015) of cobalt came from Ontario, 700 t (365 t in 2015) came from Manitoba, 887 t (849 t in 2015) came from Voisey's Bay, 3,188 t (2,391 t in 2015) came from New Caledonia, and 143 t (177 t in 2015) came from external sources, including ore from PT Vale Indonesia Tbk in 2016 (Vale S.A., 2017a, p. 51).

In 2016, some of Vale's nickel concentrate from Voisey's Bay was refined at its hydrometallurgical refinery in Long Harbour, Newfoundland and Labrador, and some was smelted and refined at Vale operations in Ontario and Manitoba. Vale continued to ramp up production at the Long Harbour refinery and began producing a cobalt intermediate product in 2016. During the quarter ending December 2016, 277 t of cobalt in intermediate product was produced at Long Harbour. Production of cobalt metal began in early 2017 (Vale S.A., 2017a, p. 18, 41, 51; 2017b, p. 18).

Vale planned to phase out smelting and refining at Thompson, owing to Canadian sulfur dioxide emission standards that came into effect in 2015. The company was allowed to continue smelting and refining through 2018, subject to negotiation of emission limits with Environment Canada (Vale S.A., 2017a, p. 40).

Glencore reported that 1,000 t of the cobalt produced at its Nikkilverk refinery in Norway originated from concentrates produced from its mines at Sudbury, Ontario, and Raglan, Quebec (800 t in 2015) (Glencore plc, 2017, p. 210).

The Fort Saskatchewan refinery, a joint venture of Sherritt and General Nickel Co. S.A., produced 3,693 t of cobalt as metal powder and briquettes in 2016 (3,733 t in 2015). Approximately 88% of the cobalt originated from Cuba; the remainder was from purchased materials. Decreased production of intermediate nickel-cobalt sulfide from Cuba was partially offset by a drawdown in intermediate sulfide inventory and the use of cobalt-rich feed from other sources. 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., 2017a, p. 11, 59–61, 90; 2017b, p. 22).

China.—China was the world's leading producer and consumer of refined cobalt. In 2016, China's total production, including an estimate for Umicore's Ganzhou Yi Hao plant, was estimated to constitute more than one-half of world refined cobalt production. China's production decreased from that of 2015, reportedly in response to poor market conditions during the first half of the year—low demand for cobalt oxide combined with excessive inventories and decreasing prices of cobalt oxides and salts. China's imports of cobalt raw materials were lower than those of 2015, primarily because of decreased imports of cobalt concentrate from Congo (Kinshasa) and of raw materials from nickel operations. In spite of reduced imports and production, China's consumption increased in 2016 from that of 2015 and stocks of cobalt oxides were drawn down. Nearly 80% of China's cobalt consumption was used to make cathode materials for rechargeable batteries (Darton Commodities Ltd., 2017, p. 33; Minor Metals Monthly, 2017, p. 17, 19; Xu, 2017, p. 4).

Numerous companies refined and (or) processed cobalt in China. In 2016, approximately 85% of China's refined cobalt was produced by 10 companies and nearly 60% was produced by 3 companies—Jinchuan, Shenzhen GEM High-Tech Co. Ltd. (including subsidiary Jiangsu Cobalt Nickel Metal Co. Ltd.), and Zhejiang Huayou Cobalt Co. Ltd. Only a small portion of China's cobalt production originated from domestic mines. Most of the production was from imported cobalt concentrate and intermediate chemical compounds, the majority of which was sourced from Congo (Kinshasa). China also imported cobalt raw materials sourced from nickel operations in Australia and elsewhere and has been recovering increasing amounts of cobalt from scrap in recent years (Xu, 2017, p. 2, 4).

China's State Reserve Bureau (SRB) continued to add cobalt metal to its national stockpile in 2016. In addition to receiving deliveries of cobalt purchased in November 2015, the SRB purchased 2,800 t in late February 2016, with delivery due before mid-July. The cobalt reportedly was sourced from domestic producers Jiangsu Cobalt Nickel Metal, Jinchuan, and Yantai CASH Industrial Co., Ltd., and the trading division of Wanbao Mining Ltd. Because domestic producers supplied cobalt metal to the SRB, China's imports of cobalt metal for domestic consumption tripled from that of 2015 (Metal Bulletin Daily, 2016; Darton Commodities Ltd., 2017, p. 34–36; Xu, 2017, p. 8).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt and was estimated to represent more than one-half of global production. Most of the country's cobalt mine production was from copper-cobalt ores mined by industrial or mechanized methods; a lesser amount was gathered by tens of thousands of artisanal miners by handpicking cobalt-rich ores. Some of Congo (Kinshasa)'s ores and concentrates were exported, some were processed in Congo (Kinshasa) to intermediate materials (crude cobalt carbonate, crude cobalt hydroxide, or cobalt-bearing alloys, such as *alliage blanc*), and some were refined in Congo (Kinshasa) to cobalt metal. China was the leading destination for Congo (Kinshasa)'s cobalt exports. The Government of Congo (Kinshasa) reportedly extended a moratorium on its 2013 ban on exports of copper and cobalt concentrates until December 31, 2016. The justification for the moratorium was the inadequate power supply to process the concentrates in the country (Ross, 2016).

State-owned La Générale des Carrières et des Mines SARL (Gécamines) held a minority interest in most of the copper-cobalt operations in Congo (Kinshasa). In 2016, Gécamines produced 50 t of refined cobalt at its Shituru refinery in Likasi, down from 240 t in 2015 (Province du Katanga Division Provinciale de Mines, 2017).

During 2016, Kamoto Copper Company SA (KCC) (Katanga Mining Ltd., Gécamines, and La Société Immobilière du Congo) continued the suspension of its copper and cobalt processing that began in September 2015. As a result, no cobalt cathode was produced from the Luilu refinery (2,901 t was produced in 2015). Ore extraction from the Kamoto underground mine and its extensions was also suspended, and mining from the KOV and Mashamba East open pits focused on waste mining with production of sufficient incidental ore for processing after the end of the suspension. KCC planned to commission its whole ore leach project during the second half of 2017 and restart ore beneficiation and concentrate refining in 2018 (table 7). Glencore was KCC's majority shareholder and had life-of-mine offtake agreements for all KCC's copper and cobalt output (Katanga Mining Ltd., 2017, p. 12–14).

Boss Mining SPRL [70% Eurasian Resources Group B.V. (ERG) and 30% Gécamines] mined copper-cobalt ore from open pits at Mukondo Mountain and Kabolela and produced oxide and sulfide concentrates at the Kakanda concentrator. In recent years, Boss Mining's oxide concentrates were exported, primarily to China, and its sulfide concentrates were sent to the Chambishi Metals plc refinery in Zambia. The company's cobalt production has steadily decreased because of changes in ore mineralogy and in August 2016, it ceased shipments of concentrate to China. Boss Mining's copper-cobalt operation included an electrowinning plant where crude cobalt carbonate was produced (Darton Commodities Ltd., 2017, p. 25–26, 30).

In 2016, Tenke Fungurume Mining S.A.R.L. [Freeport-McMoRan Inc. (FCX), Lundin, and Gécamines] extracted copper-cobalt ore from an open pit mine, which it processed onsite to produce 16,053 t of cobalt in crude cobalt hydroxide (16,014 t in 2015). The hydroxide was sold under contract or on the spot market and included sales to Freeport Cobalt Oy's Kokkola refinery in Finland and to refineries in Belgium (Umicore), China (Jinchuan and others), and Zambia

(Chambishi Metals). In May, FCX announced that it planned to sell its interest in Tenke Fungurume to reduce debt. The sale, to China Molybdenum Co., Ltd. [Luoyang, China, (CMOC)], was completed in mid-November. Lundin waived its right of first refusal to acquire FCX's interest and announced that it had entered into a definitive agreement to sell its interest to private equity firm BHR Partners (Beijing, China) (Darton Commodities Ltd., 2017, p. 10, 24; Freeport-McMoRan Inc., 2017, p. 139; Lundin Mining Corp., 2017a, p. 40; 2017b, p. 24–25).

Société Congolaise du Traitement du Terril de Lubumbashi (STL) (Groupe Forrest International and Gécamines) processed slag purchased from Gécamines via trading company Groupement du Terril de Lubumbashi (GTL) and produced alliage blanc, which reportedly has been sold to Glencore since 2015. From late February until mid-May, STL (also known as the Big Hill smelter) was shut down so that the refractory lining could be replaced (Groupe Forrest International, 2016a, b; Clowes and Wilson, 2017).

Mutanda Mining SPRL (Glencore and Fleurette Mumi Holding Ltd.) mined copper-cobalt oxide ore from open pits near Kolwezi and produced 24,500 t of cobalt in concentrate and crude cobalt hydroxide, 48% more than the 16,500 t produced in 2015. The increase in production was attributed to successful plant optimization projects and higher cobalt grades in the material processed. Glencore had an offtake agreement for all the operation's copper and cobalt production (Fleurette Group, 2017).

Chemaf SPRL (Shalina Resources Ltd.) mined copper-cobalt ore from the Etoile open pit mine and produced concentrate using heavy media separation technology, which it processed at its solvent extraction–electrowinning (SX–EW) plant at Usoke in Lubumbashi. In 2016, Chemaf reportedly constructed an additional flotation concentrator and a roaster at the Etoile Mine. As the ore chemistry changes from oxide ores to sulfide ores at the Etoile Mine, the roaster will be needed to convert the sulfide concentrates to oxide concentrates so they can be processed at the Usoke plant. Chemaf also was commissioning a new SX–EW plant at the mine site (table 7) (Darton Commodities Ltd., 2017, p. 28).

Ruashi Mining SPRL (75% Jinchuan subsidiary Metorex (Proprietary) Ltd. and 25% Gécamines) produced 3,391 t of cobalt in crude cobalt hydroxide (4,344 t in 2015) from its Ruashi operation east of Lubumbashi. The 22% decrease in production was mainly attributed to a lower supply of third-party feed, although low plant availability, processing issues, low ore grades, and adverse ore characteristics were also identified as contributing factors. Ruashi consisted of a copper-cobalt oxide open pit mine, a mill, and an SX–EW refinery. The cobalt hydroxide was shipped to Jinchuan for refining (Jinchuan Group International Resources Co. Ltd., 2017, p. 12, 37).

The La Sino-Congolaise des Mines S.A. (Sicomines) joint venture (China Railway Group Ltd., Gécamines, Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.) did not report production of copper-cobalt concentrates in 2016. China Railway had two other operating copper-cobalt mines in Congo (Kinshasa)—Luishia and Minière de Kalumbwe Myunga (China Railway Group Ltd., 2017, p. 35; Province du Katanga Division Provinciale de Mines, 2017).

Congo Dongfang International Mining SPRL (CDM), a subsidiary of Zhejiang Huayou Cobalt Co., Ltd., was responsible for procuring cobalt concentrates for Huayou's refineries in China and produced crude cobalt hydroxide at its hydrometallurgical plant in Lubumbashi. The ores and concentrates were thought to have been sourced from Compagnie Minière du Sud Katanga, Sicomines, and other mining operations, including artisanal miners. In 2016, CDM produced 24,800 t, gross weight, of cobalt hydroxide (Darton Commodities Ltd., 2017, p. 25; Province du Katanga Division Provinciale de Mines, 2017).

Compagnie Minière de Kambove (COMIKA) (Wanbao Mining and Gécamines) completed the first phase of construction on the open pit Kamoya copper-cobalt mine near Kambove, Haut-Katanga Province. In November, COMIKA began shipping concentrate and had produced 31,000 t, gross weight, of copper-cobalt concentrate, containing an estimated 300 t of cobalt, by yearend (Darton Commodities Ltd., 2018, p. 20; Province du Katanga Division Provinciale de Mines, 2017).

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 2016, the sulfide contained 33,845 t of nickel and cobalt, 9% less than the 37,020 t produced in 2015. The decrease in production was the result of a shutdown during Hurricane Matthew and higher levels of deleterious elements in ore mined from new concessions (Sherritt International Corp., 2017a, p. 89; 2017b, p. 22).

The Ernesto Che Guevara operation (also known as Punta Gorda) in Moa, Holguin Province, mined and processed nickel-cobalt laterites. In 2016, the processing plant reportedly operated at about 60% of its 30,000 t/yr of nickel plus cobalt capacity. Nickel and cobalt originating in Cuba could not be imported into the United States because of a United States embargo on imports from Cuba (Marsh, 2016).

Finland.—In 2016, Freeport Cobalt Oy (FCX, Lundin, and Gécamines) produced 29% more cobalt at its Kokkola refinery than it produced in 2015, bringing the refinery's production back to 2014 levels. The company produced a wide range of cobalt chemicals and metal powders. In 2016, the main feed for the refinery was crude cobalt hydroxide supplied under a long-term agreement by the Tenke Fungurume operation in Congo (Kinshasa). In May, FCX agreed to negotiate exclusively with CMOC to enter an agreement to sell its interest in Freeport Cobalt to CMOC. The sale had not been finalized by yearend (Darton Commodities Ltd., 2017, p. 10, 24; Freeport-McMoRan Inc., 2017, p. 23; Freeport Cobalt Oy, undated).

PJSC MMC Norilsk Nickel (Nornickel) produced two cobalt products at its Harjavalta nickel refinery—cobalt sulfate and an intermediate cobalt sulfate solution, which was refined by Freeport Cobalt. In 2016, the refinery's feed consisted of matte from Boliden AB's Harjavalta smelter, including that made from nickel concentrates produced at Nornickel's Nkomati Mine in South Africa; nickel-bearing materials from Kola MMC; and nickel-bearing intermediates from other companies, including nickel-cobalt sulfide from Talvivaara Mining Co. Plc's operation

in Finland. The nickel concentrates were toll smelted by Boliden prior to processing by Nornickel (Darton Commodities Ltd., 2017, p. 17; PJSC MMC Norilsk Nickel, 2017, p. 63–64, 110, 223).

Boliden processed nickel concentrates in its Harjavalta smelter and sold the resulting nickel matte. In June, Boliden purchased First Quantum's Kevitsa open pit nickel-copper-PGM sulfide mine and beneficiation plant. Kevitsa produced nickel concentrate containing about 11,100 t of nickel and an estimated 500 t of cobalt in 2016 (8,805 t of nickel and an estimated 420 t of cobalt in 2015). Prior to Boliden's purchase of Kevitsa, about one-third of the mine's nickel concentrate was processed at the Harjavalta smelter. After the purchase, this was increased to about two-thirds of the concentrate produced (Boliden AB, 2017a, p. 114; 2017b, p. 8; First Quantum Minerals Ltd., 2017, p. 25).

Terrafame Oy (a subsidiary of Terrafame Group Oy, owned by the Government of Finland) ramped up production from the former Talvivaara polymetallic sulfide mining and bioheap-leaching operation in Sotkamo, central Finland. In 2016, the company produced intermediate nickel-cobalt sulfide containing 9,554 t of nickel and, based on reported nickel and cobalt contents of the sulfide, an estimated 190 t of cobalt. In October, Terrafame put its second production line in the metals plant into operation. By yearend, Finland's Ministerial Committee on Economic Policy decided that negotiations to secure private financing for the operation could continue into 2017 and that additional money could be granted to Terrafame Group Oy to finance future operations (Terrafame Oy, 2017a, p. 3, 5, 114; 2017b).

France.—According to the Cobalt Development Institute (2017), Eramet s.a.'s production of cobalt chloride from its refinery at Sandouville was 11% less than production in 2015. Historically, the refinery has consumed nickel matte imported from Eramet subsidiary Société Le Nickel's Doniambo smelter in New Caledonia. Beginning in the second half of 2017, the refinery was to process matte purchased from Boliden's smelter in Finland. In late 2016, Eramet announced that it planned to sell metal powder producer Eurotungstene Poudres SAS (Grenoble) to Umicore (Thomson Reuters, 2016; Eramet s.a., 2017, p. 12–13).

India.—According to estimates by the Cobalt Development Institute (2017), India's cobalt production decreased by 33% from that of 2015. However, India's leading producers Nicomet Industries Ltd. and Rubamin Ltd. have reportedly ceased production of cobalt metal and changed to producing cobalt chemicals by processing refined metal. The reduction in refining was attributed to economic and environmental reasons (Darton Commodities Ltd., 2014, p. 7).

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. Vale Indonesia sold its matte production to Vale Canada Ltd. (80%) and Sumitomo Metal Mining Co., Ltd. (20%) under life-of-mine agreements. Most of the matte was sent to Vale's nickel refinery in Matsusaka, Mie Prefecture, Japan (Vale S.A., 2017a, p. 42–43).

Japan.—Sumitomo's production of cobalt cathode was slightly higher than that of 2015 (table 9). The company'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 and nickel matte from PT Vale in Indonesia and elsewhere. It produced cobalt chloride, most of which was converted to cobalt cathode for sale. Sumitomo's Harima refinery in Hyogo Prefecture began refining nickel and cobalt in early 2014. This plant processed nickel-cobalt sulfides from Coral Bay Nickel and Taganito to produce cobalt chloride. Cobalt chloride from Harima, and some from Niihama, was sent to Sumitomo's Isoura battery materials plant in Niihama to produce NCA battery cathode materials (Sumitomo Metal Mining Co., Ltd., 2016, p. 46, 54; Cobalt Development Institute, 2017; Darton Commodities Ltd., 2017, p. 14).

Madagascar.—In 2016, the Ambatovy joint venture (Sherritt, Sumitomo Corp., and Korea Resources Corp.) produced 3,273 t of cobalt metal (3,464 t in 2015). The decrease in production was mainly attributed to a tailings pipe blockage and subsequent shutdown for plant maintenance. The Ambatovy project mined nickel-cobalt laterite ore in east-central Madagascar, which it transported as slurried ore by pipeline to a processing plant and refinery located near the Port of Toamasina (Sherritt International Corp., 2017b, p. 7, 16).

Mexico.—Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (MMB) [Korean Consortium and Camrova Resources Inc. (formerly Baja Mining Corp., Vancouver, British Columbia, Canada)] completed commissioning of the cobalt circuit at its El Boleo copper-cobalt-zinc-manganese operation in Baja California Sur. By yearend, MMB produced 419 t of cobalt cathode. The company planned to increase its cobalt production to 50 metric tons per month in 2017 (Camrova Resources Inc., 2017, p. 10–11).

Morocco.—Cie. de Tifnout Tighanimine (CTT) [a subsidiary of Groupe Managem (Casablanca)] mined cobalt arsenide ores and produced crude cobalt hydroxide at Bou-Azzer. The hydroxide was refined to cobalt cathode and oxide at CTT's Guemassa hydrometallurgical refinery north of Marrakech. In recent years, CTT reportedly has toll refined about 300 t/yr of cobalt for another company. The data for 2015–16 in table 9 appear to include this tolled production (Darton Commodities Ltd., 2017, p. 20).

New Caledonia.—Vale Nouvelle-Calédonie S.A.S. (Vale and Société de Participation Minière du Sud Caledonien S.A.S.) continued to ramp up production at its Vale New Caledonia project in the southern tip of New Caledonia's main island. The project consisted of a nickel-cobalt laterite mine, a high-pressure acid-leaching processing plant, and a refinery. In 2016, Vale produced 3,188 t of cobalt from New Caledonia (2,391 t in 2015). Statistics from the Government of New Caledonia indicated that Vale produced 2,531 t of cobalt in carbonate (1,568 t in 2015). Following rampup, Vale New Caledonia was expected to have a nominal production capacity of 57,000 t/yr of nickel contained in nickel oxide and 4,500 t/yr of cobalt contained in an intermediate cobalt carbonate (Direction de l'Industrie, des Mines et de l'Energie, 2017; Vale S.A., 2017a, p. 42, 51).

In August, Société Le Nickel (a subsidiary of Eramet) ceased production of nickel matte at its Doniambo smelter and shifted its focus entirely to ferronickel production for economic reasons.

The matte had been sent to Eramet's refinery in Sandouville, France, where nickel products and cobalt chloride were produced (Thomson Reuters, 2016; Eramet s.a., 2017, p. 12).

Norway.—Glencore's production of cobalt cathode at its Nikkelverk refinery was 13% more than that of 2015. The company's Sudbury and Raglan operations in Canada supplied 29% of the cobalt refined at Nikkelverk; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies. The increase in production was the result of increases in cobalt recovered from feed materials sourced from company operations and those of other companies (Darton Commodities Ltd., 2017, p. 11; Glencore plc, 2017, p. 210).

Papua New Guinea.—In 2016, the Ramu Nickel joint venture (operated by majority owner Metallurgical Corporation of China Ltd.) produced 13% less cobalt in intermediate nickel-cobalt hydroxide than in 2015 (table 8). The decrease in production from its Kurumbukari nickel-cobalt laterite mine and Basamuk high-pressure acid-leaching processing plant was the result of an extended shutdown following an accident at the refinery in April. The hydroxide was exported to China to be refined by Jinchuan and Jilin Jien Nickel Industry Ltd. (Darton Commodities Ltd., 2017, p. 27; Highlands Pacific Ltd., 2017, p. 6).

Philippines.—Two high-pressure acid-leaching processing plants produced intermediate nickel-cobalt sulfides from lateritic ore mined in the Philippines—Coral Bay Nickel (a joint venture among Sumitomo, Mitsui & Co., Ltd., Sojitz Corp., and Rio Tuba Nickel Mining Corp., listed in order of share) at the Rio Tuba Mine on Palawan Island and Taganito HPAL Nickel (Sumitomo, Mitsui, and Nickel Asia Corp., listed in order of share) at Nickel Asia's Taganito Mine in the northeastern region of Mindanao Island. The Taganito plant was to be expanded by about 20% (table 7). The mixed sulfides were sent to Sumitomo's Niihama refinery in Japan (Darton Commodities Ltd., 2017, p. 14).

Russia.—Nornickel, the sole producer of refined cobalt in Russia, produced 52% more refined cobalt in 2016 than it produced in 2015 (table 9). Nornickel mined and beneficiated nickel-copper sulfide ores, smelted the concentrates, and refined the matte on the Taimyr Peninsula and the Kola Peninsula. On the Taimyr Peninsula, Nornickel's Polar Division's Nickel plant (a nickel-cobalt refinery that had been operating since 1942) produced cobalt ingot and cobalt oxide from local ores. As part of a planned reconfiguration to increase production efficiency, in 2016, Nornickel decommissioned the Polar Division's nickel smelter and Nickel plant and ceased production of cobalt ingot and oxide. Future cobalt refining was to take place at company operations in Harjavalta, Finland, and the Kola Peninsula (Cobalt Development Institute, 2017; PJSC MMC Norilsk Nickel, 2017, p. 16, 19, 83).

At Nornickel's Severonickel refinery at Monchegorsk on the Kola Peninsula, Kola MMC processed cobalt-bearing nickel materials originating from Kola, the Polar Division, and elsewhere. In 2016, Kola MMC ramped up production of high-grade cobalt cathode at its newly constructed cobalt refinery; the company also produced crude cobalt hydroxide (Darton Commodities Ltd., 2017, p. 17–18; PJSC MMC Norilsk Nickel, 2017, p. 19).

South Africa.—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Nornickel) produced 831 t of cobalt in nickel concentrate in 2016 (1,112 t in 2015). Concentrate from Nkomati was sold to Metal Trade Overseas AG and then processed at Boliden's Harjavalta smelter and Kola MMC. In October, BCL withdrew from a 2014 agreement to buy Nornickel's share in Nkomati because of a lack of funds (African Rainbow Minerals Ltd., 2016, p. 84; 2017, p. 16; Stoddard and Strydom, 2016; PJSC MMC Norilsk Nickel, 2017, p. 65, 209, 223).

Cobalt was also 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 952 t of cobalt sulfate at its base-metals refinery near Rustenburg, North West Province, 6% more than it produced in 2015 (Anglo American Platinum Ltd., 2017, p. 65). Impala Platinum Ltd. produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province. Some of the cobalt produced by Impala 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 and produced intermediate nickel sulfate containing cobalt.

Spain.—In early 2016, Lundin announced that it planned to permanently close its Aguablanca nickel-copper mine in Badajoz Province, owing to low nickel and copper prices. By yearend, Lundin had disposed of the operation and other exploration licenses in Spain by transferring its shares of Rio Narcea Recursos S.A. to Valoriza Minería [a subsidiary of Grupo Sacyr (Madrid)] (Lundin Mining Corp., 2017b, p. 3).

Turkey.—Meta Nikel Kobalt A.Ş. (Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) produced intermediate nickel-cobalt hydroxide from its high-pressure acid-leaching plant at Gordes. The plant used nickel laterite ore from mines in Gordes in Manisa Province and Yunusemre in Eskisehir Province as feed. Meta Nikel planned to increase the plant's efficiency and production capacity and to study the option of producing value-added products (Vestel Elektronik Sanayi ve Ticaret A.Ş., 2017, p. 61).

Vietnam.—Ban Phuc Nickel Mines LLP (Asian Mineral Resources Ltd.'s subsidiary AMR Nickel Ltd. and state-owned Mineral Development Co.) produced cobalt in nickel-copper concentrate, which was sent to Jinchuan for refining. In October, the mine and beneficiation plant, located about 160 km west of Hanoi in Son La Province, were placed on care-and-maintenance status, owing to sustained low nickel prices (Asian Mineral Resources Ltd., 2017, p. 8, 18).

Zambia.—Cobalt is present in many of Zambia's copper deposits, but Zambian copper operations do not report their cobalt mine output. Production of refined cobalt, which was mainly from imported concentrates, increased to levels similar to those prior to the low production of 2015.

According to the Cobalt Development Institute (2017), Chambishi Metals (90% ERG and 10% ZCCM Investments Holdings Plc) produced 4,725 t of cobalt metal at its Chambishi refinery, 58% more than the 2,997 t produced in 2015. The increase was attributed to a change in feed processed by the refinery. In recent years, the refinery mainly processed copper-

cobalt sulfide concentrate from Boss Mining's operations in Congo (Kinshasa), supplemented by crude cobalt hydroxide from Tenke Fungurume. As cobalt levels in the sulfide ores declined, Boss Mining began to process tailings and fines from former Gécamines operations to produce oxide concentrate or crude cobalt carbonate for Chambishi to refine (Darton Commodities Ltd., 2017, p. 16, 24–26).

Konkola Copper Mines Plc (KCM) (Vedanta Resources Ltd. and ZCCM Investments Holdings) mined copper ores from its Nchanga and Konkola operations. Cobalt in concentrate, mainly from the Nchanga open pit, was processed to a copper-iron-cobalt alloy at the company's Nchanga copper smelter in Chingola. In addition to feed from KCM's mines, the smelter also processed copper-cobalt concentrates from other companies. Darton Commodities Ltd. estimated that KCM's production of cobalt in alloy decreased from 1,400 t in 2015 to 300 t in 2016. KCM's decrease in cobalt production in recent years was attributed to lower feed grades from the Nchanga operation, lower availability of equipment and power, placement of the Nchanga underground mine on care-and-maintenance status in 2015, and reduced recovery rates from externally sourced concentrates (Darton Commodities Ltd., 2016, p. 19; 2017, p. 21).

China Nonferrous Mining Corp. Ltd. (CNMC) mined and processed copper-cobalt ore in the Zambian Copperbelt through four majority-owned subsidiaries—NFC Africa Mining Plc. (NFCA), CNMC Luanshya Copper Mines Plc. (CLM), Chambishi Copper Smelter Ltd. (CCS), and Sino-Metal Leach Zambia Ltd. CCS smelted copper concentrates from NFCA, CLM, and other miners. Production at CLM's Baluba Center Mine, processing plant, and slag copper recovery project remained suspended owing to inadequate electricity supply and the low price of copper. In September, CCS completed construction and began production from its High Grade Cobalt Matte Metallurgy project, which had the capacity to process 50,000 t/yr of matte and to produce cobalt in alloy, but production from the new plant was hampered by electrical power shortages (Wangwe, 2016; China Nonferrous Mining Corp. Ltd., 2017, p. 8, 30).

Consolidated Nickel Mines plc (CNM) had a lease and royalty agreement with Jinchuan for full operational control of the Munali nickel mine and concentrator in southern Zambia. CNM had all key mine infrastructure and operational permits in place and planned to restart operations at Munali within 3 months of improved nickel market conditions and receipt of development approval. The mine was expected to produce nickel concentrate containing 200 t/yr of cobalt, which would be smelted in southern Africa (Consolidated Nickel Mines plc, 2016, undated).

Glencore's Sable Zinc Kabwe Ltd. copper electrowinning plant has not operated since 2014, when it processed feed from third-party sources and produced 500 t of cobalt in hydroxide. Mopani Copper Mines Plc (Glencore, First Quantum, and ZCCM Investment Holdings, listed in order of share) kept its Nkana cobalt refinery on care-and-maintenance status in 2016 (Glencore plc, 2017, p. 206).

Zimbabwe.—The Mimosa platinum mine (Aquarius Platinum Ltd. and Impala Platinum Holdings Ltd.) produced cobalt in

concentrate, which was refined by Impala in South Africa. In April, Aquarius Platinum was acquired by Sibanye Gold (Sibanye Gold Ltd., 2016).

Zimplats Holdings Ltd. produced about 80 t of cobalt from its PGM operations in 2016 (56 t in 2015). The company was not able to finish refurbishing its mothballed base-metals refinery at its Selous Metallurgical Complex in Mashonaland West Province, owing to a lack of available cashflow. The cobalt-bearing nickel sulfate that would have been produced from the base-metals refinery was to be further refined at other refineries in Zimbabwe (Zimplats Holdings Ltd., 2016, p. 18, 61; 2017, p. 4).

Bindura Nickel Corp. (BNC) operated the Trojan nickel sulfide mine and shipped concentrate to offtake partner Glencore. During the year, BNC worked to refurbish and upgrade its nickel smelter and planned to produce a nickel leach alloy from concentrates produced at Trojan and other mines in Zimbabwe. The company's Shangani Mine and refinery remained on care-and-maintenance status (Bindura Nickel Corp., 2016, p. 3, 15).

Outlook

Historically, trends in cobalt consumption have closely followed those of global industrial production. During the 10-year period between 2007 and 2016, cobalt consumption increased at a compound annual growth rate of 5.5%. This rate is forecast to increase to 8.8% between 2017 and 2023, driven mainly by cobalt's use in rechargeable lithium-ion batteries for electric vehicles (Darton Commodities Ltd., 2018, p. 45, 53–54).

Global cobalt supply is forecast to increase in 2017 compared with that of 2016. In terms of concentrates and partially refined materials, a combined increase in production from Papua New Guinea and some operations in Congo (Kinshasa) is forecast to be greater than a combined decrease from other operations in Congo (Kinshasa) and elsewhere. In addition, high cobalt prices are expected to result in an increase in cobalt output by artisanal miners in Congo (Kinshasa). In terms of refined cobalt supply, the Cobalt Institute (2018) reported that during the first half of 2017, world production of refined cobalt was estimated to have been 18% more than that of the first half of 2016. January to June 2017 production in China, the leading source of refined cobalt, was more than 40% higher than production during the same period in 2016 (Darton Commodities Ltd., 2017, p. 37; Spencer, 2017, p. 7, 9).

Beyond 2017, global cobalt supply is expected to continue to increase. The startup of production at Katanga Mining's whole ore leach operation and Eurasian Resources Group's Metalkol operation—two large-capacity cobalt projects under development in Congo (Kinshasa) (table 7)—could provide enough intermediate cobalt hydroxide to reduce tight supply or even result in surplus cobalt supply in the near term. Beyond 2020, however, additional new supply is expected to be needed to meet the predicted growth in cobalt consumption for electric vehicles (Darton Commodities Ltd., 2018, p. 1, 4, 28; Spencer, 2017, p. 9).

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TABLE I
SALIENT COBALT STATISTICS¹

(Metric tons, cobalt content, unless otherwise specified)

	2012	2013	2014	2015	2016
United States:					
Mine production ⁶	(2)	(2)	120	760	690
Consumption:					
Reported	8,730 ^r	8,170 ^r	8,650 ^r	8,830 ^r	9,010
Apparent	9,540	8,660 ^r	8,710	10,300	11,500
Imports for consumption	11,100	10,400	11,300	11,400	12,800
Exports	3,760	3,850	4,500	3,830	4,160
Stocks, December 31:					
Industry ³	723 ^r	813 ^r	1,160	1,070 ^r	969
London Metal Exchange (LME), U.S. warehouse	51	41	9	165	195
U.S. Government:⁴					
Metal	301	301	301	301	301
Lithium-cobalt oxide		gross weight	--	--	(5)
Lithium-nickel-cobalt-aluminum oxide		do.	--	--	(5)
Price, metal:					
U.S. spot ⁶		dollars per pound	14.07	12.89	14.48
LME, cash ⁷		do.	13.06	12.26	14.00
World:					
Production:					
Mine	96,800 ^r	106,000 ^r	115,000 ^r	121,000 ^r	113,000
Refinery	77,900 ^r	86,700	92,700	99,800 ^r	96,600
Stocks, December 31, LME ⁸	429	560	489	630	691

⁶Estimated. ^rRevised. do. Ditto. -- Zero.

¹Table includes data available through May 31, 2018. Data are rounded to no more than three significant digits, except prices.

²Negligible.

³Stocks held by cobalt processors and consumers.

⁴Source: Defense Logistics Agency Strategic Materials.

⁵Less than ½ unit.

⁶Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.

⁷Annual average mean of the cash buyer price and cash seller price, minimum 99.3% cobalt briquettes, cathode, ingot, or rounds, converted from dollars per metric ton.

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

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

(Metric tons, cobalt content)

	2015	2016
Consumption by end use:		
Steels and other alloys, excludes superalloys ³	1,430 ^r	1,490
Superalloys	3,960	4,080
Cemented carbides ⁴	726	672
Chemical and ceramic uses	2,710	2,770
Total	8,830^r	9,010
Consumption by form:		
Chemical compounds, organic and inorganic ⁵	2,060	2,120
Metal	4,020 ^r	4,130
Purchased scrap	2,750	2,750
Total	8,830^r	9,010
Stocks, December 31:⁶		
Chemical compounds, organic and inorganic ⁵	475	425
Metal	W	W
Purchased scrap	W	W
Total	1,070^r	969

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

¹Table includes data available through May 31, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes estimates.

³Includes magnetic alloys, nonferrous alloys, welding materials, wear-resistant alloys, and other metallic uses not listed.

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

⁵Includes oxides.

⁶Stocks held by cobalt processors and consumers.

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

Form	HTS ² codes	2015			2016		
		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, 8105.20.9000	9,290	9,290	\$267,000	10,800	10,800	\$267,000
Oxides and hydroxides	2822.00.000	1,750	1,260	40,200	1,960	1,410	39,300
Other:							
Acetates	2915.29.3000	138	33	1,130	125	30	930
Carbonates	2836.99.1000	783	360	13,800	571	263	11,300
Chlorides	2827.39.6000	16	4	157	30	8	247
Sulfates	2833.29.1000	1,690	458	11,200	1,400	377	8,010
Total		13,700	11,400	333,000^r	14,800	12,800	327,000

^rRevised.

¹Table includes data available through May 31, 2018. 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 weights 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)			Quantity (metric tons)			Quantity (metric tons)			Quantity (metric tons)		
	Gross weight	Cobalt content ⁶	Value ⁵ (thousands)	Gross weight	Cobalt content ⁶	Value ⁵ (thousands)	Gross weight	Cobalt content ⁶	Value ⁵ (thousands)	Gross weight	Cobalt content ⁶	Value ⁵ (thousands)
2015:												
Australia	600	600	\$16,100	--	--	--	--	--	--	600	600	\$16,100
Belgium	22	22	799	563	406	\$13,300	94	25	\$727	679	453	14,800
Brazil	211	211	5,780	--	--	--	63	19	802	274	230	6,580
Canada	384	384	14,000	(7)	(7)	3	3	1	17	388	385	14,000
China	1,430 ^r	1,430 ^r	42,600 ^r	315	227	7,100	732	242	7,890	2,480 ^r	1,900 ^r	57,600 ^r
Finland	528	528	17,100	317	228	7,210	1,110	379	12,100	1,950	1,130	36,400
France	26	26	1,210	--	--	--	--	--	--	26	26	1,210
Germany	81	81	5,060	(7)	(7)	19	4	1	32	86	83	5,120
India	(7)	(7)	7	--	--	--	135	36	886	135	37	894
Italy	8	8	293	(7)	(7)	8	17	5	113	25	13	414
Japan	1,230 ^r	1,230 ^r	33,400 ^r	(7)	(7)	4	1	(7)	17	1,230 ^r	1,230 ^r	33,400 ^r
Korea, Republic of	2	2	81	20	14	272	--	--	--	21	16	353
Madagascar	840	840	24,300	--	--	--	--	--	--	840	840	24,300
Morocco	472	472	12,900	--	--	--	--	--	--	472	472	12,900
Norway	1,730	1,730	48,900	--	--	--	--	--	--	1,730	1,730	48,900
Peru	--	--	--	--	--	--	237	66	596	237	66	596
Russia	830	830	23,700	--	--	--	18	5	106	848	835	23,800
South Africa	501	501	8,870	--	--	--	--	--	--	501	501	8,870
Sweden	15	15	854	--	--	--	--	--	--	15	15	854
Uganda	26	26	674	--	--	--	--	--	--	26	26	674
United Kingdom	37	37	1,430	535	385	12,200	203	71	2,810	775	493	16,500
Zambia	308	308	7,940	--	--	--	--	--	--	308	308	7,940
Other	16	16	480	--	--	--	19	5	190	35	21	671
Total	9,290	9,290	267,000	1,750	1,260	40,200	2,630	855	26,300	13,700	11,400	333,000 ^r
2016:												
Australia	603	603	14,100	--	--	--	--	--	--	603	603	14,100
Belgium	24	24	1,010	606	436	13,000	60	16	389	690	477	14,400
Brazil	18	18	384	--	--	--	70	22	885	88	40	1,270
Canada	1,380	1,380	37,500	9	7	284	9	3	13	1,400	1,390	37,800
China	420	420	11,200	350	252	6,710	755	249	7,680	1,520	921	25,600
Finland	439	439	11,300	415	299	7,630	820	267	8,480	1,670	1,010	27,500
France	31	31	1,190	--	--	--	--	--	--	31	31	1,190
Germany	79	79	3,930	8	6	135	--	--	--	87	85	4,060
India	(7)	(7)	10	--	--	--	75	20	351	75	21	361
Japan	1,750	1,750	40,400	(7)	(7)	19	--	--	--	1,750	1,750	40,500
Macau	40	40	942	--	--	--	--	--	--	40	40	942
Madagascar	1,150	1,150	27,700	--	--	--	--	--	--	1,150	1,150	27,700
Morocco	377	377	9,000	--	--	--	--	--	--	377	377	9,000
New Caledonia	18	18	132	--	--	--	--	--	--	18	18	132
Norway	2,430	2,430	61,900	--	--	--	--	--	--	2,430	2,430	61,900
Russia	672	672	15,400	--	--	--	19	5	36	691	678	15,400
Singapore	24	24	588	--	--	--	18	5	92	42	29	680
Slovakia	--	--	--	--	--	--	112	30	497	112	30	497
South Africa	197	197	3,770	--	--	--	--	--	--	197	197	3,770
Sweden	14	14	142	--	--	--	--	--	--	14	14	142
United Kingdom	57	57	2,390	569	410	11,400	117	37	1,380	743	504	15,100
Zambia	1,030	1,030	23,800	--	--	--	--	--	--	1,030	1,030	23,800
Other	4	4	214	5	3	147	68	23	740	76	30	1,100
Total	10,800	10,800	267,000	1,960	1,410	39,300	2,120	677	20,500	14,800	12,800	327,000

See footnotes at end of table.

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

¹Revised. -- Zero.

¹Table includes data available through May 31, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

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

³HTS code 2822.00.0000.

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

⁵Customs value.

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%.

⁷Less than ½ unit.

Source: U.S. Census Bureau.

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

Country or locality	Metal ³		Oxides and hydroxides ⁴		Acetates ⁵		Chlorides ⁶		Total	
	Gross weight (metric tons)	Value ⁷ (thousands)	Gross weight (metric tons)	Value ⁷ (thousands)	Gross weight (metric tons)	Value ⁷ (thousands)	Gross weight (metric tons)	Value ⁷ (thousands)	Cobalt content ⁸ (metric tons)	Value ⁷ (thousands)
2015	3,640	\$87,000	192	\$2,690	180	\$1,390	(9)	\$7	3,830	\$91,100
2016:										
Argentina	6	203	--	--	--	--	--	--	6	203
Australia	45	813	(9)	19	--	--	--	--	46	832
Belgium	58	1,820	25	284	256	1,170	--	--	138	3,270
Brazil	37	324	17	292	--	--	--	--	49	616
Canada	1,270	11,600	1	30	--	--	--	--	1,270	11,600
China	52	2,140	(9)	8	--	--	--	--	52	2,150
Czechia	12	240	--	--	--	--	--	--	12	240
Finland	18	1,020	--	--	--	--	--	--	18	1,020
France	660	12,100	3	14	--	--	--	--	662	12,100
Germany	158	7,870	1	32	--	--	--	--	158	7,900
Hong Kong	4	206	1	36	--	--	--	--	5	242
India	67	2,490	--	--	19	148	(9)	4	71	2,650
Ireland	855	16,800	--	--	--	--	--	--	855	16,800
Israel	14	447	--	--	--	--	--	--	14	447
Italy	14	811	(9)	11	--	--	(9)	6	14	827
Japan	129	4,780	--	--	--	--	--	--	129	4,780
Korea, Republic of	56	2,530	(9)	12	--	--	--	--	56	2,540
Mexico	3	221	10	294	39	255	(9)	4	20	773
Netherlands	137	2,920	2	82	--	--	--	--	138	3,000
Singapore	24	1,420	3	110	(9)	6	--	--	26	1,540
South Africa	4	160	70	160	--	--	--	--	55	321
Switzerland	21	483	--	--	--	--	--	--	21	483
Taiwan	47	1,200	--	--	--	--	--	--	47	1,200
Turkey	32	743	--	--	--	--	--	--	32	743
United Kingdom	242	3,590	--	--	--	--	(9)	3	242	3,600
Other	19	1,160	--	--	(9)	5	--	--	19	1,170
Total	3,990	78,100	134	1,380	314	1,580	1	17	4,160	81,100

-- Zero.

¹Table includes data available through May 31, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

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

³Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy. Harmonized Tariff Schedule of the United States (HTS) codes 8105.20.0000 and 8105.30.0000.

⁴HTS code 2822.00.0000.

⁵HTS code 2915.29.3000.

⁶HTS code 2827.39.6000.

⁷Free alongside ship value.

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

⁹Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2016^{1,2}

(Metric tons, cobalt content)

Country or locality	Capacity
Australia	6,700
Belgium	1,500
Brazil	3,000 ^e
Canada	6,520 ^e
China	65,000 ^e
Congo (Kinshasa)	9,050 ^e
Finland ³	15,000
France	500
India	2,060 ^e
Japan ⁴	5,300 ^e
Madagascar	5,600
Mexico	1,700
Morocco	2,250
Norway	5,200
Russia ⁵	7,520 ^e
South Africa	1,500 ^e
Uganda	720
Zambia	9,600
Total	149,000 ^e

^eEstimated.

¹Table includes data available through May 31, 2018. 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.

³Revised upward based on capacity reported by Freeport-McMoRan Inc.

⁴Revised to include an estimate for Sumitomo Metal Mining Co., Ltd.'s Harima refinery.

⁵Revised downward because PJSC MMC Norilsk Nickel's Nickel Plant was decommissioned in 2016.

TABLE 7
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2017–21^{1,2}

Projected year of first production	Country	Project and company	Project type	Principal metal	Ore or feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2017 ^c	Australia	Rocklands Group Copper, stage 1 CuDeco Ltd.	New mine and beneficiation plant	Copper	Copper-cobalt-gold oxide and sulfide ore	730 ^{e,3}	Cobaltic-pyrite concentrate.
2017 ^c	Congo (Kinshasa)	Etoile Leach SX–EW ⁴ plant Chemaf SPRL	New refinery	do.	Copper-cobalt tailings	3,800	Cobalt hydroxide.
2017	Do.	COMMUS (Kolwezi Copper Mine) La Compagnie Minière de Musonoie Global SAS [Jin Cheng Mining Ltd. (Zijin Mining Group Co., Ltd.), La Générale des Carrières et des Mines SARL (Gécamines), and Zhejiang Huayou Cobalt Co., Ltd.]	New mine	do.	Copper-cobalt ore	NA	NA.
2017	Do.	NA Chengtun Cobalt Resource New Material (Chengtun Mining Group Co., Ltd. and Shenzhen Chengtun Rare Materials Technology Co., Ltd.)	New processing plant	do.	Copper-cobalt concentrate	3,500	Cobalt hydroxide.
2017 ^f	Do.	Project Minier, stage 2 La Sino-Congolaise des Mines S.A. (Sicomines) [China Railway Group Ltd., La Générale des Carrières et des Mines SARL (Gécamines), Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.]	Expansion of new mine and beneficiation plant; add new processing plant	do.	Copper-cobalt ore	4,600 ^{e,5}	Do.
2017 ^c	Zambia	Munali nickel mine Consolidated Nickel Mines plc	Restart production from existing mine	Nickel	Nickel-copper-cobalt-platinum-group metals sulfide ore	200	Cobalt in nickel concentrate.
2018 ^c	Australia	Esperance Nickel Sulphate Plant Alpha Fine Chemicals Ltd.	New refinery	do.	Nickel-cobalt hydroxide	100 ^e	Cobalt carbonate.
2018 ^c	Do.	Savannah North Panoramic Resources Ltd.	New mine	do.	Nickel-copper-cobalt-sulfide ore	670 ³	Nickel-copper-cobalt concentrate.
2018	Congo (Kinshasa)	Metalkol RTR [Roan Tailings Reclamation (formerly Kolwezi tailings)], phase 1 Eurasian Resources Group, La Générale des Carrières et des Mines SARL (Gécamines), and Government of Congo (Kinshasa)	New refinery	Copper	Copper-cobalt tailings	14,000	Cobalt hydroxide.
2018	Do.	WOL Project ⁶ Katanga Mining Ltd. and La Générale des Carrières et des Mines (Gécamines)	Enhancements to existing beneficiation plant and refinery	do.	Copper-cobalt oxide and sulfide ore	30,000 ⁵	Do.
2018	Japan	Harima refinery Sumitomo Metal Mining Co., Ltd.	Expansion of existing refinery	Nickel	Nickel-cobalt sulfide	850 ^{e,5}	Cobalt chloride.
2018	Philippines	Taganito Sumitomo Metal Mining Co., Ltd., Nickel Asia Corp., and Mitsui & Co., Ltd.	Expansion of existing operation	do.	Nickel-cobalt laterite ore	3,100 ^{e,5}	Nickel-cobalt sulfide.

See footnotes at end of table.

TABLE 7—Continued
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2017–21^{1,2}

Projected year of first production	Country	Project and company	Project type	Principal metal	Ore or feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2018	Zambia	Chambishi Southeast Mine NFC Africa Mining Plc (China Nonferrous Mining Corp. Ltd. and ZCCM Investment Holdings Plc)	New mine	Copper	Copper-cobalt ore	1,700 ^e	Copper-cobalt concentrate.
2019 ^f	United States (Idaho)	Idaho Cobalt eCobalt Solutions Inc. (formerly Formation Metals Inc.)	New mine and refinery	Cobalt	Stratiform cobalt-copper-gold ore	1,260 ³	Cobalt sulfate.
2019 ^{f,c}	Zambia	Synclinorium Mopani Copper Mines Plc (Glencore plc, First Quantum Minerals Ltd., and ZCCM Investment Holdings Plc)	Expansion of existing mine	Copper	Copper-cobalt ore	NA	Copper-cobalt ore.
2020 ^{f,c}	Canada	NICO Fortune Minerals Ltd.	New mine, relocated and refurbished beneficiation plant, and refinery	Cobalt	Cobalt-gold-bismuth-copper ore	1,850 ^e	Cobalt sulfate and other cobalt salts.
2020	United States (Michigan)	Eagle East Eagle Mine LLC (Lundin Mining Corp.)	New mine	Nickel-copper	Nickel-copper sulfide ore	NA	Cobalt in nickel concentrate.
2020 ^{f,c}	United States (Minnesota)	NorthMet, phase 1 PolyMet Mining Corp.	New mine and beneficiation plant	Copper	Copper-nickel-platinum-group metals sulfide ore	360	Do.
2021 ^e	Australia	Syerston Clean TeQ Metals Pty Ltd. (Clean TeQ Holdings Ltd.)	New mine and processing plant	Nickel	Nickel-cobalt laterite ore	3,200 ³	Cobalt sulfate.
2021 ^e	Congo (Kinshasa)	Musonoi Ruashi Mining Sprl [Metorex Ltd. and La Générale des Carrières et des Mines (Gécamines)]	New mine and beneficiation plant	Copper	Copper-cobalt oxide ore and copper-cobalt sulfide ore	7,500 ³	Copper-cobalt oxide ore and copper-cobalt sulfide concentrate.

^eEstimated. ^fRevised. Do., do. Ditto. NA Not available.

¹Estimated data are rounded to no more than three significant digits.

²Projects in feasibility or later stages of development in 2016. Actual startup dates may be postponed owing to economic or other factors. Additional projects might produce cobalt by 2021, but not enough information was available to include them.

³Average production.

⁴SX–EW solvent extraction–electrowinning.

⁵Total capacity following expansion.

⁶WOL whole ore leach.

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

(Metric tons, cobalt content)

Country or locality ³	2012	2013	2014	2015	2016
Australia ⁴	5,870	6,410	5,978	6,000 ^e	5,500 ^e
Botswana ⁵	195	248	196	316	281
Brazil	2,900	3,500	3,828	3,800 ^e	300 ^e
Canada ⁶	3,698 ^r	4,005 ^r	3,907 ^r	4,339 ^r	4,245 ^p
China ^e	2,200 ^r	2,600 ^r	2,800 ^r	3,000 ^r	3,100
Congo (Kinshasa) ^{e,7}	52,000	56,000	62,000 ^r	66,000 ^r	64,000
Cuba ^{e,8}	4,700 ^r	4,000 ^r	3,700	4,300	5,100
Finland ^e	635	750	770	440	690
Indonesia ^{e,9}	1,700	1,700	1,300	1,300	1,200
Madagascar ^{e,10}	600 ^r	2,400 ^r	3,400 ^r	4,000 ^r	3,800
Mexico ^e	--	--	--	--	980
Morocco ^{e,11}	2,000	2,000	2,150	2,250 ^r	2,400
New Caledonia ^{e,12}	2,670	3,190	4,040	3,690 ^r	3,390
Papua New Guinea ¹³	469	1,013	2,134	2,505	2,191
Philippines ^{e,14}	2,700	2,800	4,600	4,300	4,100
Russia ^{e,15}	6,300	6,300	6,300	6,200	5,500
South Africa ^e	2,500	3,000	3,000	2,900 ^r	2,300
United States ^{e,15,16}	--	--	120	760	690
Vietnam ¹⁵	--	25 ^e	223	277	134
Zambia ¹⁷	5,435	5,919	4,600 ^e	4,000 ^{r,e}	3,000 ^e
Zimbabwe ¹⁸	195	319	358	355 ^r	409
Total	96,800 ^r	106,000 ^r	115,000 ^r	121,000 ^r	113,000

^eEstimated. ^pPreliminary. ^rRevised. -- Zero.

¹Table includes data available through February 8, 2018. 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.

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

³In addition to the countries and (or) localities listed, Spain and Turkey are known to produce ores that contain cobalt, but information was inadequate to make reliable estimates of production. Poland produced copper ore containing 1,500 to 5,000 metric tons per year of cobalt, which was not recovered. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

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

⁵Reported cobalt content of pelletized nickel-copper matte.

⁶Recoverable cobalt in ores and concentrates shipped.

⁷Determined from estimated cobalt content of ores, concentrates, refined cobalt metal, and intermediate products such as crude cobalt alloys, crude cobalt hydroxide, and crude cobalt carbonate, produced from cobalt ores and concentrates, tailings, and slags sourced from Congo (Kinshasa).

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

⁹Cobalt content of nickel matte plus estimated cobalt in lateritic ore processed in Australia.

¹⁰Data are estimated cobalt content of ore production based on reported cobalt metal powder production and nickel recovery rates.

¹¹Cobalt content of concentrate estimated from reported gross weight.

¹²Cobalt contained in the following materials: 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.

¹³Cobalt content of nickel-cobalt hydroxide.

¹⁴Cobalt contained in the following materials: nickel-cobalt sulfide produced in the Philippines and lateritic nickel ore exported to Australia.

¹⁵Cobalt content of concentrates.

¹⁶Negligible production prior to 2014.

¹⁷Data for 2012–13 were reported by the Bank of Zambia.

¹⁸Production reported by the Zimbabwe National Statistics Agency.

TABLE 9
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY OR LOCALITY^{1,2}

(Metric tons, cobalt content)

Country or locality and form	2012	2013	2014	2015	2016
Australia, metal powder and oxide hydroxide ³	4,859 ⁴	4,981	5,419	5,150	3,350 ^e
Belgium, metal powder, oxide, hydroxide ^{3,5}	4,200	5,415	5,850	6,306	6,329
Brazil, metal	1,750	1,871	1,350	1,300 ³	400 ³
Canada, metal, metal powder, oxide	5,775 ^r	5,602	5,491	6,126 ^r	6,355 ^p
China, metal, metal powder, oxide, salts ^{e,3,6}	29,800	36,100	39,300	48,700	45,000
Congo (Kinshasa), metal ⁷	3,021	2,777	2,859	3,141	82
Finland, metal powder and salts ⁸	10,562	10,798	12,551	9,615	12,393
France, chloride ³	326	308	219	133	119
India, metal and salts ³	800	295	100	150	100
Japan, metal ³	2,542	2,747	3,654	4,259	4,305
Madagascar, metal powder	493	2,083	2,915	3,464	3,273
Mexico, metal	--	--	--	--	419
Morocco, metal	1,314	1,353	1,391	1,982 ^r	2,081
Norway, metal ⁹	2,969	3,348	3,600	3,100	3,500
Russia, metal ³	2,186	2,368	2,302	2,040	3,092
South Africa, metal powder and sulfate	1,102	1,294	1,332	1,300	1,101
Uganda, metal ³	556	376	--	--	--
Zambia, metal ³	5,669 ¹⁰	5,000	4,317	2,997	4,725
Total	77,900 ^r	86,700	92,700	99,800 ^r	96,600

^eEstimated. ^pPreliminary. ^rRevised. -- Zero.

¹Table includes data available through February 8, 2018. 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.

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

³Production reported by the Cobalt Development Institute, except as noted.

⁴Production reported by the Cobalt Development Institute and Glencore plc.

⁵Production from Umicore N.V./S.A.; includes production from China that is not otherwise included in this table.

⁶Production from domestic and imported ores, concentrates, and intermediate materials; excludes production by Umicore N.V./S.A. that is included under Belgium.

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

⁸Production reported by the Geological Survey of Finland.

⁹Data were reported by Xstrata plc for 2012, the Geological Survey of Norway for 2013, and Glencore plc for 2014–16.

¹⁰Includes production reported by Zambian Chamber of Mines.