



2017 Minerals Yearbook

COBALT [ADVANCE RELEASE]

COBALT

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In 2017, world production of refined cobalt increased by 22% to 117,000 metric tons (t) (table 9). The increase was mainly the result of higher production in China, where 64% of the world's refined cobalt was produced. The United States did not refine cobalt in 2017. World cobalt mine production increased by 10% to 120,000 t (table 8). Congo (Kinshasa) remained the leading producer of mined cobalt, supplying more than 60% of world production, followed by Russia, Australia, Cuba, and the Philippines. 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 (PGMs) ore in Montana. No cobalt has been sold from the National Defense Stockpile (NDS) since 2009. Salient U.S. and world cobalt statistics for 2013–17 are listed in table 1.

According to the Cobalt Institute (2018), preliminary data indicated that, in 2017, world apparent consumption of cobalt increased by about 9,500 t from that of 2016 to approximately 101,500 t. The increase continued to be driven mainly by increased consumption of cobalt for rechargeable batteries, although consumption in nonbattery applications also increased. In addition, purchases of cobalt metal by commodity trading firms and purchases by various entities for investment purposes continued in 2017. As a result, the supply of cobalt metal went into deficit, cobalt prices continued the upward trend that began in 2016, and by yearend 2017 they had more than doubled from yearend 2016 (Bedder, 2018, p. 3; Darton Commodities Ltd., 2018, p. 34–35; Heppel, 2018b).

Cobalt is a metallic element 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

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt during 2017. During the calendar year, the DLA Strategic Materials acquired 90 kilograms (kg), gross weight, of lithium-cobalt oxide (LCO); 470 kg, gross weight, of lithium-nickel-cobalt-aluminum oxide (NCA); and less than 300 kg,

gross weight, of cobalt alloys. The Annual Materials Plan for fiscal year 2018 (October 1, 2017, through September 30, 2018), 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, 2017).

Production

Lundin Mining Corp. (Canada) produced copper and nickel concentrates from the Eagle nickel-copper mine northwest of Marquette, MI, and the mill in Humboldt Township. In 2017, Eagle produced nickel concentrate containing 22,081 t of nickel and an estimated 640 t of cobalt, based on reported quarterly nickel production and ore grades and a forecast for annual cobalt ore grade from a 2013 production schedule (24,114 t of nickel and 690 t of cobalt in 2016). The decrease in nickel and estimated cobalt production was attributed to planned mine sequencing in 2017. The concentrate was sent by rail to smelters in North America or to ports for shipment overseas (Wardell Armstrong International Ltd., 2013, p. 8; Lundin Mining Corp., 2018a, p. 27; 2018b, p. 18).

Sibanye Gold Ltd. (South Africa), trading as Sibanye-Stillwater, produced negligible amounts of cobalt in nickel sulfate at its PGM mining and refining operations in southeastern Montana. The nickel sulfate was sold to other companies.

In early 2017, the U.S. Forest Service authorized a land exchange to transfer surface property over and around PolyMet Mining Corp.'s NorthMet mineral rights in exchange for non-Federal land owned by PolyMet. By yearend, the land exchange had been approved by the U.S. House of Representatives and sent to the U.S. Senate for consideration. During August and September, the Minnesota Department of Natural Resources released six draft water appropriation permits and two draft dam safety permits for the NorthMet project for public review and comment. Phase 1 of the NorthMet copper-nickel-cobalt 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 orebody. PolyMet continued to work on construction finance; the company expected construction and rampup to commercial production to take 24 to 30 months after receiving the permits (table 7) (PolyMet Mining Corp., 2018, p. 3–6, 17).

Micon International Ltd. and SNC Lavalin Inc. completed a feasibility study on eCobalt Solutions Inc.'s Idaho Cobalt project. The study evaluated an underground cobalt-copper-gold mine and beneficiation plant at the mine site in Lemhi County

and a hydrometallurgical plant in Bingham County to refine the bulk concentrate to battery-grade cobalt sulfate with byproduct copper sulfate, gold, and magnesium sulfate. The project would produce an average of about 1,100 metric tons per year (t/yr) of cobalt during a 12.5-year mine life. In response to market feedback and discussions with potential offtakers, eCobalt decided to reduce capital and operating costs and improve construction timelines for the project by omitting the refining stage and producing a “clean” (low-arsenic) cobalt concentrate and a byproduct copper-gold concentrate. The company engaged Micon, SNC Lavalin, and Dundee Sustainable Technologies Inc. to conduct detailed metallurgical testing and engineering for the revised flowsheet and engaged Micon to evaluate a newly developed mine design and production schedule with the aim to reduce planned dilution and improve project economics (table 7) (eCobalt Solutions Inc., 2017; 2018, p. 1).

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

Cobalt was recovered from secondary (scrap) materials by subsidiaries of Umicore N.V./S.A. (Belgium) and Plansee Group (Austria). The Umicore Specialty 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 2017 was slightly more than that of 2016. Metallurgical and chemical industries each used slightly more cobalt than they did in 2016 (table 2). 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 2017, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 23% less than that in 2016 (table 1). The decrease was primarily a result of lower imports and higher exports in 2017, compared with those in 2016.

Prices

The annual average U.S. spot price for electrolytic cobalt (cobalt cathode, minimum of 99.8% cobalt), as reported by Platts Metals Week, was \$26.97 per pound, more than twice that of 2016 (table 1). The price trended upward from \$15.00 to \$15.70 per pound in early January to \$36.00 to \$37.00 per pound at yearend. Trends in Platts’ prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were similar to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was \$26.26 per pound, and the annual average of weekly prices for Russian cobalt was \$25.90 per pound.

Hedge funds and other investors continued to purchase cobalt in expectation of potential future cobalt supply shortfalls and higher prices. Darton Commodities Ltd. (2018, p. 54) estimated that between late 2015 and yearend 2017, as much as 10,000 t of cobalt metal may have been removed from the market. China’s State Reserve Bureau purchased 5,000 t of cobalt from late 2015 into 2016. Additional cobalt metal was stocked by investment funds and trading firms for speculative purposes. By early 2017, half a dozen hedge funds reportedly had bought and stockpiled about 6,000 t of cobalt (Xu, 2016, p. 16; Harris, 2017).

In 2017, Arak Resources Ltd. changed its name to Cobalt 27 Capital Corp. (Canada) and redirected its efforts to become a resource trading company to facilitate investment in the cobalt market. Cobalt 27 planned to acquire and hold physical cobalt, enter into streaming contracts and net smelter return royalty agreements, and (or) invest in mines or early stage exploration and development projects containing cobalt. During the year, the company entered into royalty agreements pertaining to seven exploration-stage properties in Canada (four cobalt-silver properties in Ontario, two silver-lead-zinc-cobalt properties in Yukon, and one copper-zinc-cobalt property in British Columbia) and purchased more than 2,980 t of cobalt metal. At yearend, Cobalt 27 held 2,681.9 t of cobalt metal, which it stored in London Metal Exchange Ltd. (LME) warehouses in the United States and Europe (Cobalt 27 Capital Corp., 2018, p. 2–3, 6–7).

Cobalt metal, in the form of broken and cut cathode, ingots, rounds, and coarse-grain metal powder, was traded on the LME. In early 2017, the LME announced that it would be increasing the minimum purity of cobalt metal to be delivered under the cobalt contract from 99.3% to 99.8% cobalt, effective January 19, 2018. The move was prompted by PJSC MMC Norilsk Nickel (Nornickel) ceasing production of cobalt ingots in 2016, as these were the only LME-listed brands with a minimum cobalt content of 99.3%. Sherritt International Corp. (2018, p. 10) reported that the amount of cobalt traded on the LME in 2017 increased by 81% to 14,261 t, but that the LME cobalt contract was still in the early stage of acceptance and remained 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. In October, the LME announced that it planned to launch a contract for cobalt sulfate, because of its increasing use in batteries for electric vehicles (London Metal Exchange Ltd., The, 2017; Metal Registration Ltd., 2017).

Cobalt was also traded on the Chinese Stainless Steel Exchange (CSSE, Wuxi, Jiangsu Province). In 2017, CSSE delivered 2,964 t of cobalt, more than three times the 843 t delivered in 2016 (Metal Bulletin Daily, 2018b).

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 2017, net import reliance as a percentage of apparent consumption was 69%. Because U.S. cobalt mine production was exported to be refined, this indicates that 69% of U.S. cobalt supply was from imports and stock releases of refined cobalt, and 31% 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 2017, the United States imported 11,900 t of cobalt contained in metal and chemical compounds, valued at \$576 million, 7% less than the 12,800 t imported in 2016. On the basis of cobalt content, 10 countries supplied 92% of U.S. imports. Norway was the leading supplier, followed by Canada, Japan, China, Finland, Madagascar, the United Kingdom, Belgium, Russia, and Zambia (tables 3, 4). The United States also imported cobalt waste and scrap (1,550 t, gross weight, valued at \$23.3 million), unwrought cobalt alloys (418 t, gross weight, valued at \$18.4 million), and wrought cobalt and cobalt articles (208 t, gross weight, valued at \$30.5 million).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 5,730 t, valued at \$123 million, 38% more by weight of contained cobalt than the 4,160 t exported in 2016. On the basis of cobalt content, Canada was the leading destination for these exports, followed by Ireland, France, the United Kingdom, Belgium, Germany, Japan, and Australia (table 5). The United States also exported 1,190 t, gross weight, of wrought metal and cobalt articles valued at \$102 million.

World Review

World cobalt mine and refinery production each increased in 2017 compared with production in 2016. The increases were the result of a 10,000-t increase in estimated mine production in Congo (Kinshasa), the leading global producer of mined cobalt (table 8), and an increase of about 25,000 t in estimated refinery production in China, the leading global producer of refined cobalt (table 9).

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.

A 2016 Amnesty International report that brought attention to the working conditions associated with artisanal mining in Congo (Kinshasa) highlighted health and safety hazards, child workers, 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 sourcing of cobalt (Amoruso, 2017).

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 may also 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.

The following review by country focuses mainly on operations that produced cobalt in 2017. Expansions to those operations, operation restarts, and greenfield projects that were forecast to begin producing between 2018 and 2022 are listed in table 7.

Australia.—In 2017, cobalt mine production as a byproduct of nickel mining in Western Australia and Australian production of refined cobalt each decreased (tables 8, 9). A number of nickel mines from which cobalt had been produced in the past remained on care-and-maintenance status. The first of these operations ceased production in late 2008, and additional shutdowns continued into 2017, owing to low nickel prices.

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 concentrates; and the Kwinana nickel refinery, which produced cobalt in intermediate cobalt-nickel sulfide. In 2017, BHP announced that it planned to build a 100,000-t/yr nickel sulfate plant at the Kwinana refinery and could also produce cobalt sulfate if it increased the recovery rate for cobalt at the Kalgoorlie smelter and added a cobalt circuit at Kwinana (BHP Billiton Plc, 2017, p. 57, 238–239; Haegel, 2017, p. 3, 16; Daly, 2018).

First Quantum Minerals Ltd. (Canada) produced intermediate nickel-cobalt hydroxide from its Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant in Western Australia. In 2017, the plant produced 17,837 t of nickel and, based on the hydroxide containing 40% nickel and 1.4% cobalt, an estimated 620 t of cobalt, down from 23,624 t of nickel and an estimated 830 t of cobalt in 2016. Ravensthorpe operated through the end of September and then was placed on care-and-maintenance status because of persistent low nickel prices (First Quantum Minerals Ltd., 2018, p. 11).

Independence Group NL ramped up production at its Nova underground nickel-copper-cobalt sulfide mine east of Norseman, Western Australia. During the calendar year, Independence produced 400 t of cobalt in nickel concentrate, which was committed for sale to BHP Billiton's Nickel West operation and Glencore for the first 3 years of operation. Production guidance for the fiscal year beginning July 1, 2017, was 800 to 1,050 t of cobalt in concentrate (Independence Group NL, 2017, p. 12, 14; 2018, p. 3).

Minara Resources Ltd. (Glencore plc) produced 3,000 t of cobalt metal at its Murrin Murrin nickel-cobalt laterite mining and pressure-acid-leaching operation in Western Australia, a decrease from 3,200 t in 2016. The decrease in production was attributed to a maintenance shutdown during the first half of the year. In addition, approximately 300 t of Murrin Murrin's 2017 production was from third-party feed, compared with 400 t in 2016 (Glencore plc, 2018, p. 71, 208).

Belgium.—Darton Commodities Ltd. (2017, p. 13–14; 2018, p. 7) estimated that Umicore's production of refined cobalt at its Olen refinery was 7% higher in 2017 than in 2016. The refinery produced primarily cobalt metal powder and oxides; its feed included cobalt recovered by the company's recycling operation in Hoboken. In addition to the Olen refinery, which was being upgraded and expanded (table 7), Umicore refined various cobalt materials, including copper and cobalt concentrates, to produce cobalt oxides and salts in Ganzhou, Jiangxi Province, China. According to the Cobalt Institute (2018), Umicore produced 10% more refined cobalt from its two refineries in 2017 than it produced in 2016. The company also had cobalt processing plants, which made specialty chemicals or metal powders from refined cobalt, intermediates, or scrap, in Arab, AL, LaVergne, TN, and Wickliffe, OH; Bruges, Belgium; Fort Saskatchewan, Alberta, Canada; Jiangmen, Guangdong Province, China; Grenoble, France; and Cheonan, Republic of Korea (Umicore N.V./S.A., undated).

Brazil.—In mid-2016, the nickel business of Votorantim Metais S.A. was consolidated under Companhia Brasileira de Alumínio, an investee company of Votorantim S.A. The nickel-cobalt laterite mining and processing operation in Niquelandia, Goiás State, and refinery at Sao Miguel Paulista, Sao Paulo State, remained under care-and-maintenance status while the company waited for the nickel price to stabilize at a higher level (Votorantim S.A., 2018, p. 44).

Canada.—Vale S.A.'s global cobalt production was 5,811 t in 2017, essentially unchanged from the 5,799 t produced in 2016. Vale produced 1,675 t (1,851 t in 2016) of refined cobalt metal at its Port Colborne, Ontario, refinery; 1,231 t (zero in 2016) of refined cobalt metal at its Long Harbour, Newfoundland and Labrador, refinery; 2,780 t (3,188 t in 2016) of cobalt in a cobalt intermediate product at its nickel operation in New Caledonia; and 125 t (761 t in 2016) of cobalt contained in other intermediate products such as nickel concentrates. Vale's cobalt originated from company-owned nickel sulfide mines at Sudbury in Ontario, Thompson in 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 840 t (882 t in 2016) of cobalt came from Sudbury, 138 t (700 t in 2016) came from

Thompson, 1,829 t (887 t in 2016) came from Voisey's Bay, 2,780 t (3,188 t in 2016) came from New Caledonia, and 224 t (143 t in 2016) came from external sources, including ore from PT Vale Indonesia Tbk (Vale S.A., 2018, p. 55).

In 2017, Vale shipped a greater portion of the nickel concentrate produced at Voisey's Bay to its hydrometallurgical refinery in Long Harbour than in 2016; the remaining nickel concentrate was smelted and refined at Vale operations in Ontario and Manitoba. During the year, Vale began production of refined cobalt at Long Harbour, in the form of electrolytic metal rounds. Vale was phasing out smelting and refining at Thompson, owing to Canadian sulfur dioxide emission standards that came into effect in 2015. The company shut down one furnace in 2017 and planned to shut the remaining furnace in 2018. Most of the future nickel concentrate produced at Thompson was to be sent to Sudbury and Long Harbour for refining (Vale S.A., 2018, p. 3, 8).

Glencore reported that 800 t of the cobalt produced at its Nikkelverk refinery in Norway originated from concentrates produced from its mines at Sudbury, Ontario, and Raglan, Quebec (1,000 t in 2016) (Glencore plc, 2018, p. 208).

The Fort Saskatchewan refinery, a joint venture of Sherritt and General Nickel Co. S.A., produced 3,601 t of cobalt as metal powder and briquettes in 2017 (3,693 t in 2016). Approximately 88% of the cobalt originated from Cuba; 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., 2018, p. 11, 89–90).

China.—China was the world's leading producer and consumer of refined cobalt. In 2017, China's total production, including an estimate for Umicore's Ganzhou Yi Hao plant, was estimated to constitute more than 60% of world refined cobalt production. China's estimated production was 75,000 t, a 50% increase from 49,900 t in 2016, when production had declined in response to low demand, excessive inventories, and decreasing prices (table 9). China's consumption of refined cobalt increased by 26% from that of 2016, with about 80% used to make cathode materials for rechargeable batteries (Darton Commodities Ltd., 2018, p. 30–31; Minor Metals Monthly, 2018, p. 10; Xu, 2018, p. 4).

Numerous companies refined and (or) processed cobalt in China. In 2017, nearly 90% of China's refined cobalt was produced by 10 companies and about 55% was produced by 3 companies—Jinchuan Group Co. Ltd., 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 intermediate chemical compounds, the majority of which was sourced from Congo (Kinshasa). China's imports of cobalt concentrates have decreased in recent years, as more concentrates have been processed to intermediates within Congo (Kinshasa). China's refineries also processed imported cobalt raw materials sourced from nickel operations, imported intermediate cobalt alloy (alliage blanc), and cobalt from scrap. In 2017, despite an estimated increase of 24% in imports of cobalt raw materials, China's refineries reportedly had difficulty

getting enough feed materials to support increased production (Darton Commodities Ltd., 2018, p. 30–33; Xu, 2018, p. 2–3).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt and was estimated to represent more than 60% of global production (table 8). 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. The Government of Congo (Kinshasa) reportedly extended a moratorium on its 2013 ban on exports of copper and cobalt concentrates, because of inadequate power supply to process the concentrates in the country. Most of Congo (Kinshasa)'s ores and concentrates were processed in Congo (Kinshasa) to intermediate materials (mainly crude cobalt hydroxide, but also some crude cobalt carbonate and cobalt-bearing alloys, such as *alliage blanc*). Some concentrates were exported, and only small quantities were refined in Congo (Kinshasa) to cobalt metal. The amount of cobalt refined to metal within Congo (Kinshasa) was forecast to increase over the next 5 years, however, because cobalt salts producers in China were expected to shift from processing cobalt intermediates to processing cobalt metal for economic and environmental reasons (Metal Bulletin Daily, 2017b; Roskill Information Services Ltd., 2017).

Artisanal mining filled the role of a swing producer, increasing during periods of supply deficits and higher prices. Heppel (2018a) estimated that artisanal mining nearly tripled to more than 19,000 t of contained cobalt in 2017, from about 6,500 t in 2016. This was at the upper end of the range for artisanally mined cobalt production estimated by other analysts (10,000 t to 20,000 t of contained cobalt) (Darton Commodities Ltd., 2018, p. 25; Wilson and Farchy, 2018).

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) and has been the sole producer of refined cobalt in the country since late 2015, when Kamoto Copper Company SA (KCC) ceased production at its Luilu cobalt refinery. In 2017, Gécamines produced 120 t of refined cobalt at its Shituru refinery in Likasi, up from 50 t in 2016 (Province du Katanga Division Provinciale de Mines, 2018).

In December, KCC [Katanga Mining Ltd. (a subsidiary of Glencore plc), Gécamines, and La Société Immobilière du Congo] commissioned phase 1 of the whole ore leach project at its copper-cobalt mining and refining operation in Lualaba Province and began producing copper cathode. KCC expected to begin cobalt production in early 2018 and announced a production guidance of 11,000 t/yr of cobalt in hydroxide for the year. In 2017, KCC began design work to upgrade and debottleneck the Luilu cobalt plant, so that it could reliably produce the anticipated average life-of-mine production of 30,000 t/yr of cobalt in hydroxide (table 7). Glencore was KCC's majority shareholder and had life-of-mine offtake agreements for all of KCC's copper and cobalt output (Katanga Mining Ltd., 2018, p. 2, 5, 7, 23).

Boss Mining SPRL [70% Eurasian Resources Group B.V. (ERG), 40% of which is owned by the Government of Kazakhstan) 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, the company's mine production decreased because of changes in mineralogy of the ore being mined at the open pits, so it has also produced cobalt oxide concentrates from tailings generated by past mining operations within its license area. The concentrates were refined by Chambishi Metals plc in Zambia. Boss Mining's copper-cobalt operation included an electrowinning plant where crude cobalt carbonate was produced (Darton Commodities Ltd., 2017, p. 16, 25–26; 2018, p. 15).

In 2017, Tenke Fungurume Mining S.A.R.L. [China Molybdenum Co., Ltd. (CMOC), BHR Equity Investment Fund Management Co. (BHR Partners), and Gécamines] extracted copper-cobalt ore from an open pit mine, which it processed onsite to produce 16,419 t of cobalt in crude cobalt hydroxide (16,053 t in 2016). The hydroxide was sold to Freeport Cobalt Oy's Kokkola refinery in Finland under a long-term agreement and to refiners in China and elsewhere. In July, CMOC announced that it had entered into an agreement with battery material producer Ningbo Shanshan Co. to cooperate on battery raw material projects. Under the agreement, if cobalt production at the Tenke operation was expanded, Ningbo Shanshan would be given priority to purchase the incremental output. CMOC budgeted a cobalt production volume of 16,000 to 17,500 t of cobalt in hydroxide in 2018 (Darton Commodities Ltd., 2017, p. 10, 24; 2018, p. 10–11, 19; China Molybdenum Co., Ltd., 2018, p. 18, 20, 56).

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 Ltd. (GTL) and produced *alliage blanc*, which reportedly had been sold to Glencore since 2015. In March, Gécamines blocked GTL's access to the Big Hill slag heap, claiming that STL had exceeded the total cobalt production limit allowed under GTL's contract with Gécamines. STL continued production until August, when its slag inventory was depleted. The dispute had not been settled by yearend, and production could not restart until after the furnace's entire refractory lining was replaced, which was expected to take 9 to 12 months (Clowes and Wilson, 2017; Darton Commodities Ltd., 2018, p. 21).

Mutanda Mining SPRL (Glencore, 100%) mined copper-cobalt oxide ore from open pits near Kolwezi and produced 23,900 t of cobalt in concentrate and crude cobalt hydroxide, slightly less than the 24,500 t produced in 2016. Mutanda's copper production decreased by 8% in 2017, owing to lower throughput from unusually wet weather and power constraints at the company's Mopani operation in Zambia, which led to an interruption in sulfuric acid supply to Mutanda. In 2017, Glencore acquired Fleurette Group's share in Mutanda Mining (Glencore plc, 2018, p. 6, 69–70, 192).

Chemaf SARL (Shalina Resources Ltd.) mined copper-cobalt oxide and sulfide ores from the Etoile open pit mine. Concentrate from Etoile was processed to copper cathode and crude cobalt hydroxide at Chemaf's solvent extraction–electrowinning (SX–EW) plant at Usoke in Lubumbashi. In early 2017, Chemaf commissioned the cobalt circuit at its newly constructed SX–EW plant at the Etoile Mine site and

began producing crude cobalt hydroxide. This expanded the types of materials that Chemaf could process and increased the company's total production capacity to 6,200 t/yr of cobalt as hydroxide. Chemaf planned to build a third refinery as part of its Mutoshi project (table 7) (Chemaf SARL, 2018; Darton Commodities Ltd., 2018, p. 20).

Ruashi Mining SPRL [Jinchuan subsidiary Metorex (Proprietary) Ltd. and Gécamines] produced 4,638 t of cobalt in crude cobalt hydroxide (3,391 t in 2016) from its Ruashi operation east of Lubumbashi. The increase in production was attributed to process improvements and a higher cobalt feed grade. Ruashi consisted of three open pit copper-cobalt oxide mines and an SX–EW refinery. The cobalt hydroxide was offered for sale on the international market (Jinchuan Group International Resources Co. Ltd., 2018, p. 11–12).

The La Sino-Congolaise des Mines S.A. (Sicomines) joint venture (China Railway Group Ltd., Gécamines, Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.) produced about 1,600 t, gross weight, of cobalt hydroxide in 2017. China Railway had two other operating copper-cobalt mines in Congo (Kinshasa)—Luishia and Minière de Kalumbwe Myunga (China Railway Group Ltd., 2018, p. 31; Province du Katanga Division Provinciale de Mines, 2018).

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. In 2017, CDM produced about 25,100 t, gross weight, of cobalt hydroxide (24,800 t in 2016). The ores and concentrates reportedly were sourced from CDM's mines and other mining operations, including artisanal miners (Darton Commodities Ltd., 2017, p. 25; 2018, p. 19; Province du Katanga Division Provinciale de Mines, 2018).

Compagnie Minière de Kambove (COMIKA) (Wanbao Mining Ltd. and Gécamines) produced about 45,800 t, gross weight, of copper-cobalt concentrate from the open pit Kamoya copper-cobalt mine near Kambove, Haut-Katanga Province (Province du Katanga Division Provinciale de Mines, 2018).

In 2017, subsidiaries of China Nonferrous Mining Corp. Ltd. (CNMC) and Yunnan Copper Industry Group Co., Ltd. formed the Lualaba Copper Smelter SAS joint venture (LCS) to build a copper smelter. As part of the project, LCS was developing a "cobalt recycling system" to produce 10,000 t/yr of crude copper-cobalt alloy (table 7) (China Nonferrous Mining Corp. Ltd., 2018, p. 38, 117).

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 2017, the sulfide contained 34,595 t of nickel and cobalt (33,845 t in 2016) (Sherritt International Corp., 2018, p. 89).

The Government-owned Empresa Niquelífera Ernesto Che Guevara operation (also known as Punta Gorda) in Moa, Holguin Province, mined and processed nickel-cobalt laterites. During 2017, Empresa Niquelífera Ernesto Che Guevara focused on lowering the cost of production. Nickel and cobalt

originating in Cuba could not be imported into the United States because of a United States embargo on imports from Cuba (Thomson Reuters, 2017a).

Finland.—According to the Cobalt Institute (2018), in 2017, Freeport Cobalt Oy [Freeport-McMoRan Inc. (FCX), Lundin, and Gécamines] produced 9% more cobalt at its Kokkola refinery than it produced in 2016. The company produced a wide range of cobalt chemicals and metal powders. In 2017, 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 June, FCX and CMOC agreed to terminate discussions on CMOC's acquisition of the Kokkola refinery; the refinery remained for sale at yearend (Thomson Reuters, 2017b; Darton Commodities Ltd., 2018, p. 10–11, 19; Freeport-McMoRan Inc., 2018, p. 22; Freeport Cobalt Oy, undated).

Nornickel produced two cobalt products at its Harjavalta nickel refinery—refined cobalt sulfate and an intermediate cobalt sulfate solution, which was refined by Freeport Cobalt. In 2017, most of the refinery's nickel feed was sourced from company operations in Russia (matte from Kola MMC); third-party feed consisted of matte from Boliden AB's Harjavalta smelter and nickel salts from other companies. In June, Nornickel and BASF SE signed a memorandum of understanding and began to negotiate an agreement under which Norilsk would supply cobalt and nickel from Harjavalta to BASF for the production of lithium-ion battery cathode materials in Europe (BASF SE and PJSC MMC Norilsk Nickel, 2017; PJSC MMC Norilsk Nickel, 2018, p. 6, 66–67, 84–85).

Boliden's Kevitsa open pit nickel-copper-PGM sulfide mine and beneficiation plant produced nickel concentrate containing 13,777 t of nickel and 587 t of cobalt in 2017 (compared with about 11,100 t of nickel and an estimated 500 t of cobalt in 2016). The company's Harjavalta smelter processed nickel concentrates from Kevitsa and elsewhere and sold the resulting nickel matte. As a result of upgrades to the flash furnace in 2017, the smelter will require less frequent maintenance (Boliden AB, 2018, p. 35, 60, 115).

Terrafame Ltd. [Terrafame Group Ltd. (Government of Finland), Galena Asset Management S.A. (Trafigura Group), and Sampo plc] continued to stabilize and ramp up production from the former Talvivaara polymetallic sulfide mining and bioheap-leaching operation in Sotkamo, central Finland. In 2017, the company produced intermediate nickel-cobalt sulfide containing 20,864 t of nickel and, based on reported nickel and cobalt contents of the sulfide in 2016, an estimated 420 t of cobalt (9,554 t nickel and an estimated 190 t cobalt in 2016). In February, Terrafame and Trafigura Ventures V B.V. established an agreement for Trafigura to purchase all of Terrafame's nickel-cobalt sulfide for the next 7 years. In November, Terrafame announced that it planned to enhance the operation by adding a refinery that would convert its nickel-cobalt sulfide into chemicals for battery applications. The refinery would have the capacity to produce about 150,000 t/yr, gross weight, of nickel sulfate and 5,000 t/yr, gross weight, of cobalt sulfate (table 7) (Terrafame Ltd., 2017a, p. 114; 2017b; 2018, p. 7, 16–17, 96).

France.—Eramet s.a.'s production of cobalt chloride from its refinery at Sandouville during 2016 and 2017 was lower than typical levels because of an 11-month shutdown to upgrade the

refinery to handle a change in feed composition. Prior to the shutdown, the refinery consumed nickel matte from Eramet subsidiary Société Le Nickel's Doniambo smelter in New Caledonia. When Société Le Nickel decided to cease producing matte, Eramet established a long-term supply agreement with Boliden for matte from its Harjavalta smelter. After rampup, Eramet expected to produce 400 t/yr of cobalt at the refinery (Thomson Reuters, 2016; Eramet s.a., 2017; 2018, p. 37).

India.—According to estimates by the Cobalt Institute (2018), India's cobalt production was unchanged from that of 2016. However, India's leading producers Nicomet Industries Ltd. and Rubamin Ltd. reportedly ceased production of cobalt metal in 2014 and changed to producing cobalt chemicals by processing refined metal (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 sold to Vale was sent to the company's nickel refinery in Matsusaka, Mie Prefecture, Japan (Vale S.A., 2018, p. 46–47).

Japan.—Sumitomo's production of refined cobalt was 3% less than that of 2016 (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, nickel matte from PT Vale in Indonesia, and additional raw materials from elsewhere. It produced cobalt chloride, most of which was converted to electrolytic cobalt (cobalt cathode) for sale. Sumitomo's Harima refinery in Hyogo Prefecture processed nickel-cobalt sulfides from Coral Bay Nickel and Taganito to produce cobalt chloride. Some of the cobalt chloride from Harima and Niihama was sent to Sumitomo's Isoura battery materials plant in Niihama to produce NCA battery cathode materials (Darton Commodities Ltd., 2017, p. 14; Sumitomo Metal Mining Co., Ltd., 2017, p. 52–53; Cobalt Institute, 2018).

Madagascar.—In 2017, the Ambatovy joint venture (Sumitomo Corp., Korea Resources Corp., and Sherritt) produced 3,053 t of cobalt metal (3,273 t in 2016). The production was below guidance because of reduced acid availability resulting from acid plant equipment failures, reliability issues with the pressure acid-leaching circuit, and other unplanned maintenance activities. Nickel-cobalt laterite ore was mined in east-central Madagascar and transported by pipeline to a processing plant and refinery near the Port of Toamasina (Sherritt International Corp., 2018, p. 5).

Mexico.—Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (MMB) [Korean Consortium and Camrova Resources Inc. (Canada)] owned and operated the El Boleo project, which consisted of an underground copper-cobalt-zinc mine and a refinery in Baja California Sur. During the year, the operation's copper production was only 60% of the amount planned, owing to lower feed grade, throughput, and recovery rates at the plant than expected (Camrova Resources Inc., 2018, p. 5).

Morocco.—Compagnie de Tifnout Tighanimine (CTT) (a subsidiary of Groupe Managem) mined cobalt arsenide ores and produced crude cobalt hydroxide at Bou-Azzer. The hydroxide

was refined to electrolytic cobalt (cobalt cathode) and oxide at CTT's Guemassa hydrometallurgical refinery north of Marrakech. CTT reportedly toll refined some cobalt for another company. The data for 2015–17 in table 9 are thought to include this tolled production. The 8% decrease in refined production in 2017 was attributed to a decrease in ore grade (Darton Commodities Ltd., 2018, p. 16; Groupe Managem, 2018, p. 22).

New Caledonia.—In 2017, estimated recoverable mine production decreased by 18% compared with that of 2016 (table 8) because Société Le Nickel was no longer producing matte from which cobalt was recovered and no lateritic ore was exported to Australia for refining. 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 2017, Vale produced 2,780 t of cobalt from New Caledonia (3,188 t in 2016). Following rampup over the next 5 to 6 years, 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. Vale wanted to sell an equity stake in Vale New Caledonia to help fund the operation (Schvartsman and others, 2017, p. 52; Vale S.A., 2018, p. 46, 55).

Norway.—Glencore's production of electrolytic cobalt (cobalt cathode) at its Nikkelverk refinery was the same as that of 2016 (table 9). The company's Sudbury and Raglan operations in Canada supplied 23% of the cobalt refined at Nikkelverk; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies (Darton Commodities Ltd., 2017, p. 11; Glencore plc, 2018, p. 208).

Papua New Guinea.—In 2017, the Ramu Nickel joint venture (operated by majority owner Metallurgical Corporation of China Ltd.) produced 51% more cobalt in intermediate nickel-cobalt hydroxide than in 2016 (table 8). Production from the Kurumbukari nickel-cobalt laterite mine and Basamuk high-pressure acid-leaching processing plant had been ramped up to exceed the operation's design capacity of 3,300 t/yr of contained cobalt. The hydroxide was exported to China to be refined by Jinchuan and Jilin Jien Nickel Industry Ltd. (Darton Commodities Ltd., 2018, p. 20; Highlands Pacific Ltd., 2018, 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. In 2017, production capacity at the Taganito plant was expanded by about 20% to an estimated 5,900 t/yr of cobalt contained in nickel-cobalt sulfides. The mixed sulfides were sent to Sumitomo's Niihama refinery in Japan (Darton Commodities Ltd., 2017, p. 14; 2018, p. 13–14).

Russia.—Nornickel, the sole producer of refined cobalt in Russia, produced 33% less refined cobalt than it produced in 2016 (table 9). The company mined and beneficiated nickel-

copper sulfide ores and smelted the concentrates at its Polar Division on the Taymyr Peninsula and at Kola MMC on the Kola Peninsula. The resulting matte from the Polar Division was refined at Kola MMC's newly constructed Severonickel refinery at Monchegorsk on the Kola Peninsula, where high-grade electrolytic cobalt (cobalt cathode) was produced. Matte from Kola MMC was refined at Severonickel and by Norilsk Nickel Harjavalta Oy in Finland. In addition to producing refined cobalt, Norinickel reportedly also produced about 2,000 t of cobalt in crude cobalt hydroxide in 2017, about one-half of which was exported, and the remainder was either stockpiled or processed in Russia (Cobalt Institute, 2018; Darton Commodities Ltd., 2018, p. 15; PJSC MMC Norilsk Nickel, 2018, p. 66–67).

South Africa.—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Norinickel) produced 851 t of cobalt in nickel concentrate in calendar year 2017 (831 t in 2016). Concentrate from Nkomati was sold to Metal Trade Overseas AG and processed at Kola MMC and elsewhere (African Rainbow Minerals Ltd., 2017, p. 41; 2018, p. 53; PJSC MMC Norilsk Nickel, 2018, p. 86).

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 cobalt sulfate at its base-metals refinery near Rustenburg, North West Province, and reported that its total production of base metals was 4% less than that of 2016, owing to a change in mineralogy of the ore being mined (Anglo American Platinum Ltd., 2018, p. 79). Impala Platinum Holdings Ltd. (Implats) produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province. In addition to refining concentrates from PGM ore mined in South Africa, some of the cobalt produced by Implats was recovered from concentrates produced at the Mimosa platinum mine in Zimbabwe. Two other platinum producers—Lonmin plc and Northam Platinum Ltd.—operated base-metals refineries and produced crude nickel sulfate containing cobalt. Lonmin had a project with Thakadu Battery Materials Pty. Ltd. to refine its crude sulfate to battery grade nickel sulfate and byproduct cobalt hydroxide (table 7). For the fiscal years ending June 30, 2017, and June 30, 2018, Northam reported sales of 7 t and 10 t of cobalt in nickel sulfate, respectively, from its base-metals recovery plant at Zondereinde (Creamer, 2018; Northam Platinum Ltd., 2018, p. 5, 39).

Turkey.—Meta Nikel Kobalt A.Ş. (Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) exported 23,130 t of intermediate nickel-cobalt hydroxide containing nearly 4,000 t of nickel and 220 t of cobalt from its high-pressure acid-leaching plant at Gordes. The plant used nickel laterite ore from mines in Gordes in Manisa Province and Yunussemre 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., 2018, p. 59).

Vietnam.—Asian Mineral Resources Ltd. explored options for its Ban Phuc nickel mine and beneficiation plant in Son La Province, which were for sale. The operation was placed on care-and-maintenance status in late 2016, owing to sustained low

nickel prices. Before ceasing production, cobalt-bearing nickel-copper concentrate produced from Ban Phuc had been sent to Jinchuan for refining (Asian Mineral Resources Ltd., 2018).

Zambia.—Cobalt is present in many of Zambia's copper deposits, but not all Zambian copper operations report their cobalt mine output. Some of Zambia's mined cobalt is recovered in alloy intermediates at copper smelters within the country. Estimated production of mined cobalt for 2013–16 was revised downward on the basis of an analysis of available information, including reports from Darton Commodities Ltd. In 2017, mine production increased from a historical low in 2016. Production of refined cobalt, which was mainly from imported concentrates, decreased by nearly 50% from production in 2016 (tables 8, 9).

According to the Cobalt Institute (2018), Chambishi Metals (90% ERG and 10% ZCCM Investments Holdings Plc) produced 2,520 t of cobalt metal at its Chambishi refinery, 47% less than the 4,725 t produced in 2016. The decrease was attributed to a reduction in feed from Boss Mining's operations in Congo (Kinshasa). As a result of lower production levels at the Chambishi refinery and the variable quality of the metal produced, ERG reportedly purchased cobalt metal from other sources to fill its long-term contracts (Metal Bulletin Daily, 2017a; Darton Commodities Ltd., 2018, p. 15).

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, in recent years the smelter also processed copper-cobalt concentrates from other companies. Darton Commodities Ltd. estimated that KCM's production of cobalt in alloy increased by 125% to 900 t in 2017. Vedanta planned to increase its investment in KCM's operations and was evaluating options to produce 3,000 to 4,000 t/yr of refined cobalt for the battery industry, instead of copper-iron-cobalt alloy (Darton Commodities Ltd., 2016, p. 19; 2018, p. 17; Lewis, 2017).

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. In April 2017, CNMC restarted its slag copper recovery project and produced 1,219 t of copper-cobalt alloy containing 123 t of cobalt by yearend. CLM's Baluba Center Mine remained on care-and-maintenance status during the year, although the company was preparing to resume production. NFCA began construction on a new copper-cobalt mine and processing plant from which cobalt hydroxide would be produced (table 7) (China Nonferrous Mining Corp. Ltd., 2018, p. 30–32, 36).

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 2017 (Glencore plc, 2018, p. 204).

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

concentrate, which was refined by Implats in Springs, South Africa (Implats Platinum Holdings Ltd., 2018).

Zimplats Holdings Ltd. produced about 80 t of cobalt from its PGM operations in 2017, similar to production in 2016. 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 cash flow (Zimplats Holdings Ltd., 2018a, p. 31; 2018b, p. 3).

Bindura Nickel Corp. (BNC) produced cobalt-containing concentrate from the Trojan nickel sulfide mine. During the year, BNC's majority shareholder, Asa Resource Group plc, went under administration and planned to sell its shareholding in BNC (newZWire, 2018).

Outlook

Historically, trends in cobalt consumption have closely followed those of global industrial production. Increases in cobalt consumption by the battery industry, mainly for personal electronics, have resulted in global annual growth rates in cobalt consumption exceeding growth rates for the global gross domestic product. During the 10-year period between 2007 and 2016, cobalt consumption increased at a compound annual growth rate of 5.5%. This rate was forecast to increase to 8.8% for the 7-year period between 2017 and 2023, driven mainly by cobalt's potential use in rechargeable lithium-ion batteries for electric vehicles (Darton Commodities Ltd., 2018, p. 45, 53–54). Bedder (2018, p. 3, 6) reported a similar trend; from 2010 to 2017, cobalt consumption by the battery sector increased by 13.5% per year, leading to an increase in total world cobalt consumption of 8% per year. The total world consumption rate was forecast to increase to 10% per year between 2017 and 2027.

Global cobalt supply is forecast to continue to increase. Cobalt mine and intermediate production are expected to increase significantly in the near term, particularly from the rampup of production of cobalt hydroxide from three large projects in Congo (Kinshasa). Katanga Mining's whole ore leach operation (designed to produce more than 30,000 t/yr of contained cobalt) is expected to begin producing cobalt in 2018, and in 2019, Chemaf's Mutoshi operation (16,000 t/yr of contained cobalt) and ERG's Metalkol RTR operation (14,000 t/yr of contained cobalt) are expected to begin production (table 7). Production from these and other, smaller projects could provide enough cobalt raw materials to 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 (Katanga Mining Ltd., 2017; Bedder, 2018, p. 10; Darton Commodities Ltd., 2018, p. 1, 4, 28; Metal Bulletin Daily, 2018a; Roskill Information Services Ltd., 2018).

References Cited

- African Rainbow Minerals Ltd., 2017, Integrated annual report 2017: Sandton, South Africa, African Rainbow Minerals Ltd., 136 p. (Accessed April 8, 2019, at https://www.arm.co.za/im/files/annual/2017/ARM_IAR2017.pdf.)
- African Rainbow Minerals Ltd., 2018, Interim results for the six months ended 31 December 2017: Sandton, South Africa, African Rainbow Minerals Ltd., 96 p. (Accessed April 8, 2019, at https://www.arm.co.za/im/files/results/interim_31dec17.pdf.)
- Amnesty International, 2016, Democratic Republic of Congo—"This is what we die for"—Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt: London, United Kingdom, Amnesty International, January 19, 87 p. (Accessed April 27, 2018, at <https://www.amnesty.org/download/Documents/AFR6231832016ENGLISH.PDF>.)
- Amoruso, Brigitte, 2017, Responsible sourcing—Setting the scene for cobalt: The Cobalt Conference, Cobalt Development Institute, Marrakech, Morocco, May 17–18, presentation, 7 p.
- Anglo American Platinum Ltd., 2018, Integrated report 2017: Johannesburg, South Africa, Anglo American Platinum Ltd., 148 p. (Accessed June 21, 2018, at <http://www.angloamericanplatinum.com/~media/Files/A/Anglo-American-Platinum/annual-report-2017/anglo-platinum-integrated-report-2017.pdf>.)
- Asian Mineral Resources Ltd., 2018, Asian Mineral Resources update on strategic review for Ban Phuc Nickel Mine in Vietnam and announcement of financing agreement: Toronto, Ontario, Canada, Asian Mineral Resources Ltd., April 24, 2 p. (Accessed May 10, 2018, at http://asianmineralres.com/media/23650/Press-release-April-24_18.pdf.)
- BASF SE and PJSC MMC Norilsk Nickel, 2017, BASF and Norilsk Nickel enter exclusive negotiations to cooperate on raw material supply for battery materials production in Europe: Ludwigshafen, Germany, and Moscow, Russia, BASF SE and PJSC MMC Norilsk Nickel press release, June 27. (Accessed April 5, 2019, at https://www.nornickel.com/upload/iblock/a28/nornickel_basf_eng_final_full.pdf.)
- Bedder, Jack, 2018, Supply-side changes in the cobalt market: The Cobalt Conference, Cobalt Development Institute, Las Vegas, NV, May 23–24, presentation, 12 p.
- BHP Billiton Plc, 2017, Annual report 2017: London, United Kingdom, BHP Billiton Plc, 292 p. (Accessed July 12, 2018, at <https://www.bhp.com/~media/documents/investors/annual-reports/2017/bhpanualreport2017.pdf>.)
- Boliden AB, 2018, 2017 annual report: Stockholm, Sweden, Boliden AB, 121 p. (Accessed July 30, 2018, at <https://vp217.alertir.com/afw/files/press/boliden/201803060710-1.pdf>.)
- Camrova Resources Inc., 2018, Management's discussion and analysis—Year ended December 31, 2017: Toronto, Ontario, Canada, Camrova Resources Inc., March 27, 14 p. (Accessed August 16, 2018, at http://www.camrovaresources.com/assets/camrovaresourcesmda2745910_pp.pdf.)
- Chemaf SARM, 2018, Meeting demand for today and tomorrow: Lubumbashi, Congo (Kinshasa), Chemaf SARM corporate brochure, 11 p. (Accessed September 24, 2018, at <http://www.chemaf.com/wp-content/uploads/2018/07/Chemaf-corporate-brochure.pdf>.)
- China Molybdenum Co., Ltd., 2018, 2017 annual report: Luoyang City, China, China Molybdenum Co., Ltd., 260 p. (Accessed May 18, 2018, at http://www.chinamoly.com/06invest/DOC/2018/E_03993_04207.pdf.)
- China Nonferrous Mining Corp. Ltd., 2018, 2017 annual report: Beijing, China, China Nonferrous Mining Corp. Ltd., 236 p. (Accessed April 30, 2018, at <http://www.cnmc.net/Managed/Resources/docs/report/ar2017e.pdf>.)
- China Railway Group Ltd., 2018, 2017 annual report: Beijing, China, China Railway Group Ltd., 264 p. (Accessed September 21, 2018, at http://www.ir-cloud.com/china/601390/financial/21/EN/2017%20Annual%20Report_RHC1FNbFABLk.pdf.)
- Clowes, W., and Wilson, T., 2017, Dispute at Congo cobalt mine heads to court, halts supply: Bloomberg, November 27. (Accessed November 27, 2017, at <https://www.bloomberg.com/news/articles/2017-11-27/dispute-at-congo-cobalt-mine-heads-to-court-halts-metal-supply>.)
- Cobalt 27 Capital Corp., 2018, Management's discussion & analysis—Eight months ended December 31, 2017: Toronto, Ontario, Canada, Cobalt 27 Capital Corp., April 28, 27 p. (Accessed May 9, 2018, at http://www.co27.com/_resources/financials/Co27-YE-2017-MD&A-Apr-30-2018.pdf.)
- Cobalt Institute, 2018, 2017 CI production statistics: Cobalt News Magazine, no. 2, April, p. 3–8. (Accessed May 8, 2020, at <https://www.cobaltinstitute.org/assets/files/cobalt-news/2018%20Cobalt%20News/Cobalt-News-Ap2018.pdf>.)
- Creamer, Martin, 2018, Thakadu's nickel plant secures R50m black industrialist grant: Creamer Media's Engineering News, January 23. (Accessed April 23, 2019, at https://www.engineeringnews.co.za/article/thakadus-nickel-plant-secures-r50m-black-industrialist-grant-2018-01-23/rep_id:4136.)

- Daly, Tom, 2018, BHP Billiton to produce nickel sulphate next year, eyeing cobalt on battery boom: Shanghai, China, Thomson Reuters, April 18. (Accessed July 12, 2018, at <https://www.reuters.com/article/us-china-metals-batteries-bhp/bhp-billiton-to-produce-nickel-sulphate-next-year-eyeing-cobalt-on-battery-boom-idUSKBN1HP13M>.)
- Darton Commodities Ltd., 2014, Cobalt market review 2013–2014: Guildford, United Kingdom, Darton Commodities Ltd., January, 46 p.
- Darton Commodities Ltd., 2016, Cobalt market review 2015–2016: Guildford, United Kingdom, Darton Commodities Ltd., January, 41 p.
- Darton Commodities Ltd., 2017, Cobalt market review 2016–2017: Guildford, United Kingdom, Darton Commodities Ltd., January, 57 p.
- Darton Commodities Ltd., 2018, Cobalt market review 2017–2018: Guildford, United Kingdom, Darton Commodities Ltd., February, 59 p.
- Defense Logistics Agency Strategic Materials, 2017, Annual Materials Plan for FY 2018: Fort Belvoir, VA, Defense Logistics Agency Strategic Materials news release, October 1, 1 p. (Accessed October 17, 2017, at https://www.dla.mil/Portals/104/Documents/Strategic%20Materials/Announcements/3135%20FY18%20AMP_ACQ.pdf?ver=2017-09-29-133651-237.)
- eCobalt Solutions Inc., 2017, eCobalt SEDAR files positive feasibility study for the Idaho Cobalt Project—Pre-tax NPV \$176M, IRR 25.1%: Vancouver, British Columbia, Canada, eCobalt Solutions Inc., November 10, 8 p. (Accessed April 8, 2019, at <https://www.sedar.com/GetFile.do?lang=EN&docClass=8&issuerNo=00007056&issuerType=03&projectNo=02693938&docId=4209807>.)
- eCobalt Solutions Inc., 2018, Management’s discussion and analysis for the 10 months ended December 31, 2017: Vancouver, British Columbia, Canada, eCobalt Solutions Inc., March 20, 21 p. (Accessed May 8, 2020, at <https://www.sedar.com/GetFile.do?lang=EN&docClass=7&issuerNo=00007056&issuerType=03&projectNo=02746801&docId=4283415>.)
- Eramet s.a., 2017, Eramet Sandouville’s new facilities opened: Paris, France, Eramet s.a. news release, July 3. (Accessed May 8, 2020, at <http://www.eramet.com/en/eramet-sandouilles-new-facilities-opened>.)
- Eramet s.a., 2018, Annual report 2017: Paris, France, Eramet s.a., 59 p. (Accessed May 8, 2020, at https://www.eramet.com/sites/default/files/2019-05/eramet_ra_2017_complet_en_web_1.pdf.)
- First Quantum Minerals Ltd., 2018, 2017 annual report: Vancouver, British Columbia, Canada, First Quantum Minerals Ltd., 100 p. (Accessed May 8, 2020, via <https://sedar.com/DisplayCompanyDocuments.do?lang=EN&issuerNo=00006237>.)
- Freeport Cobalt Oy, [undated], Products: Kokkola, Finland, Freeport Cobalt Oy. (Accessed August 3, 2018, at <https://www.freeportcobalt.com/products/index.html>.)
- Freeport-McMoRan Inc., 2018, Form 10–K—2017: U.S. Securities and Exchange Commission, 197 p. (Accessed August 3, 2018, at https://s22.q4cdn.com/529358580/files/doc_financials/10-K/10_k2017.pdf.)
- Glencore plc, 2018, Annual report 2017: Baar, Switzerland, Glencore plc, 220 p. (Accessed May 8, 2020, at <https://www.glencore.com/dam/jcr:d6c11311-5076-44b6-af40-dee29142d663/glen-2017-annual-report.pdf>.)
- Global Tungsten & Powders Corp., 2014, Global Tungsten & Powders announces strategic cobalt partnership with Umicore: Towanda, PA, Global Tungsten & Powders Corp. news release, August 27. (Accessed April 25, 2019, at <http://www.pm-review.com/global-tungsten-powders-announces-strategic-cobalt-partnership-with-umicore/>.)
- Groupe Managem, 2018, Communication financière—Résultats annuels 2017 [Financial communication—Annual results 2017]: Casablanca, Morocco, Groupe Managem presentation, March 23, 49 p. (Accessed August 16, 2018, via <http://www.managemgroup.com/Investisseurs/Resultats-Financiers/Presentations2>.)
- Haegel, Eduard, 2017, The Nickel West journey continues: Australian Nickel Conference, Paydirt Media Pty. Ltd., Perth, Western Australia, Australia, presentation, October 17, 16 p. (Accessed July 12, 2018, at https://www.bhp.com/-/media/documents/media/reports-and-presentations/2017/171710_austriannickelconferencepresentation.pdf.)
- Harris, Caroline, 2017, Hedge funds accumulate stockpile of cobalt, electric carmakers race to secure shipments: StreetSignals, February 24. (Accessed May 8, 2020, at <https://streetsignals.com/hedge-funds-accumulate-stockpile-of-cobalt-electric-carmakers-race-to-secure-shipments/>.)
- Heppel, George, 2018a, Artisanal mining will balance the cobalt market: London, United Kingdom, CRU International Ltd., October 1. (Accessed May 8, 2020, at <https://www.crugroup.com/knowledge-and-insights/insights/2018/artisanal-mining-will-balance-the-cobalt-market/>.)
- Heppel, George, 2018b, The year of cobalt—Disconnect between market fundamentals and prices: The Cobalt Conference, Cobalt Development Institute, Las Vegas, NV, May 23–24, presentation, 8 p.
- Highlands Pacific Ltd., 2018, Annual report 2017: Brisbane, Queensland, Australia, Highlands Pacific Ltd., 63 p. (Accessed May 8, 2020, at <https://www.asx.com.au/asxpdf/20180320/pdf/43slcwqzq25cz7.pdf>.)
- Impala Platinum Holdings Ltd., 2018, Fact sheet—Mimosa: Northlands, South Africa, Impala Platinum Holdings Ltd. fact sheet, 8 p. (Accessed April 8, 2019, at <http://www.implats.co.za/pdf/fact-sheets/2019/mimosa-fact-sheets-dec-2018.pdf>.)
- Independence Group NL, 2017, Annual report 2017: South Perth, Western Australia, Australia, Independence Group NL, 130 p. (Accessed May 8, 2020, at <http://www.igo.com.au/annualreport/2017/>.)
- Independence Group NL, 2018, Quarterly report for the period ending 31 December 2017: South Perth, Western Australia, Australia, Independence Group NL, 20 p. (Accessed May 8, 2020, at https://www.igo.com.au/site/PDF/1054_0/December2017QuarterlyActivitiesReport.)
- Jinchuan Group International Resources Co. Ltd., 2018, 2017 annual report: Hong Kong, China, Jinchuan Group International Resources Co. Ltd., 200 p. (Accessed May 17, 2018, at http://www.jinchuan-intl.com/uploaded_files/investor/677/e2362_ar_eng.pdf.)
- Katanga Mining Ltd., 2017, Katanga Mining announces commissioning of the core of the first train of whole ore leach plant and provides an operational update: Whitehorse, Yukon Territory, Canada, Katanga Mining Ltd., December 11, 3 p. (Accessed May 13, 2019, at <http://www.katangamining.com/~media/Files/K/Katanga-mining-v2/media/newsreleases/news2017/pr-11-12-2017-v2.pdf>.)
- Katanga Mining Ltd., 2018, Management’s discussion and analysis for the years ended December 31, 2017 and 2016: Whitehorse, Yukon Territory, Canada, Katanga Mining Ltd., 37 p. (Accessed June 21, 2018, at <http://www.katangamining.com/~media/Files/K/Katanga-mining-v2/reports-and-presentations/2017-12-kml-mda-final.pdf>.)
- Lewis, Barbara, 2017, Vedanta explores ways to produce cobalt for batteries: London, United Kingdom, Thomson Reuters, August 15. (Accessed August 16, 2017, at <https://uk.reuters.com/article/us-vedanta-agm/vedanta-explores-ways-to-produce-cobalt-for-batteries-idUKKCNI1AV0RZ>.)
- London Metal Exchange Ltd., The, 2017, LME announces strategic pathway delivery programme: London, United Kingdom, The London Metal Exchange Ltd. press release, October 30. (Accessed May 9, 2018, at <https://www.lme.com/News/Press-room/Press-releases/Press-releases/2017/10/LME-announces-strategic-pathway-delivery-programme>.)
- Lundin Mining Corp., 2018a, Annual information form for the year ended December 31, 2017: Toronto, Ontario, Canada, Lundin Mining Corp., March 29, 73 p. (Accessed May 8, 2020, at <https://www.sedar.com/GetFile.do?lang=EN&docClass=1&issuerNo=00025806&issuerType=03&projectNo=02751446&docId=4287542>.)
- Lundin Mining Corp., 2018b, Management’s discussion and analysis for the year ended December 31, 2017: Toronto, Ontario, Canada, Lundin Mining Corp., February 15, 47 p. (Accessed May 8, 2020, at <https://www.sedar.com/GetFile.do?lang=EN&docClass=7&issuerNo=00025806&issuerType=03&projectNo=02729720&docId=4258327>.)
- Metal Bulletin Daily, 2017a, ERG buys cobalt as Boss feed exports to Chambishi drop: could cause price spike: Metal Bulletin Daily, no. 9518.3, July 19, p. 2–3. (Accessed July 21, 2017, via <https://www.metalbulletin.com>.)
- Metal Bulletin Daily, 2017b, Interview—Cobalt metal will be used as major feed for cobalt refining—Hanrui Cobalt: Metal Bulletin Daily, no. 9527.2, September 19, p. 2. (Accessed September 21, 2017, via <https://www.metalbulletin.com>.)
- Metal Bulletin Daily, 2018a, Interview—Cobalt boom ‘guaranteed’ for 7–10 years—ERG’s Southgate: Metal Bulletin Daily, no. 9546.3, February 7, p. 16. (Accessed February 12, 2018, via <https://www.metalbulletin.com>.)
- Metal Bulletin Daily, 2018b, LME Asia Week—Chinese Stainless Steel Exchange importance grows: Metal Bulletin Daily, no. 9559.3, May 9, p. 20. (Accessed August 22, 2018, via <https://www.metalbulletin.com>.)
- Metal Registration Ltd., 2017, LME—Rulebook—Cobalt rules amendments: London, United Kingdom, Metal Registration Ltd., January 23. (Accessed May 8, 2020, at <https://metalreg.com/news/lme-rulebook-cobalt-rules-amendments/>.)
- Minor Metals Monthly, 2018, Cobalt—China’s cobalt market commentary for January 2018: Minor Metals Monthly [published by Beijing Antaike Information Development Co., Ltd., or Antaike], no. 214, February, p. 8–17.

- newswire, 2018, UK firm strikes deal to take over Zim nickel producer BNC: newswire, December 19. (Accessed May 2, 2019, at <https://newswire.live/uk-firm-strikes-deal-to-take-over-zim-nickel-producer-bnc/>.)
- Northam Platinum Ltd., 2018, Annual integrated report 2018: Jukskei View, South Africa, Northam Platinum Ltd., 310 p. (Accessed April 23, 2019, at <http://northam.integrated-report.com/2018/>.)
- PJSC MMC Norilsk Nickel, 2018, Annual report 2017: Moscow, Russia, PJSC MMC Norilsk Nickel, 295 p. (Accessed September 26, 2018, at https://www.nornickel.com/upload/iblock/f36/Annual_Report_2017.pdf.)
- PolyMet Mining Corp., 2018, Annual information form for the eleven months ended December 31, 2017: Toronto, Ontario, Canada, PolyMet Mining Corp., 59 p. (Accessed October 22, 2018, at <http://polymetmining.com/wp-content/uploads/2018/03/SEDAR1-2017-12-31-AIF.pdf>.)
- Province du Katanga Division Provinciale de Mines, 2018, Statistiques des notes de débit relatives à la redevance minière émises de janvier à décembre 2017 (ex Katanga declarees a Lubumbashi) [Debit note statistics for the mining royalty issued from January to December 2017 (ex Katanga declared in Lubumbashi)]: Lubumbashi, Congo (Kinshasa), Province du Katanga Division Provinciale de Mines, January 6. (Accessed August 23, 2018, at http://congominer.org/system/attachments/assets/000/001/459/original/compil%C3%A9_redevance_mini%C3%A8re_2017.pdf?1521447795.)
- Roskill Information Services Ltd., 2017, Cobalt—DRC delays ban on exports... again: Roskill Information Services Ltd., January 18. (Accessed January 18, 2017, at <https://roskill.com/news/cobalt-drc-delays-ban-exportsagain/>.)
- Roskill Information Services Ltd., 2018, Cobalt—Trafigura signs deal with Chemaf for cobalt hydroxide: Roskill Information Services Ltd., April 17. (Accessed April 26, 2018, at <https://roskill.com/news/cobalt-trafigura-signs-deal-with-chemaf-for-cobalt-hydroxide/>.)
- Schvartsman, F., Osorio, L.E., Pereira, A., Poppinga, P., Maki, J., and Pires, L.S., 2017, Vale Day—New York 2017—The premium mining player: New York, NY, Vale S.A. investor presentation, December 6, 70 p. (Accessed May 8, 2018, at http://www.vale.com/EN/investors/information-market/presentations-webcast/PresentationsWebcastsDocs/Vale%20Day%202017_%20vSite.pdf.)
- Sherritt International Corp., 2018, 2017 annual information form: Toronto, Ontario, Canada, Sherritt International Corp., 101 p. (Accessed May 18, 2018, at [https://s2.q4cdn.com/343762060/files/doc_financials/2017/Sherritt-AIF-Printer-Version-\(revised\).pdf](https://s2.q4cdn.com/343762060/files/doc_financials/2017/Sherritt-AIF-Printer-Version-(revised).pdf).)
- Sumitomo Metal Mining Co., Ltd., 2017, Integrated report 2017: Tokyo, Japan, Sumitomo Metal Mining Co., Ltd., 161 p. (Accessed July 24, 2018, at http://www.smm.co.jp/E/ir/library/annual/2017/pdf/2017EN_All.pdf.)
- Terrafame Ltd., 2017a, Annual report 2016: Tuhkakyta, Finland, Terrafame Ltd., 191 p.
- Terrafame Ltd., 2017b, Terrafame Ltd. plans nickel and cobalt chemicals production for battery applications: Tuhkakyta, Finland, Terrafame Ltd. media release, November 10, 2 p. (Accessed July 31, 2018, at <https://www.terrafame.com/media/terrafame-ltd.-plans-nickel-and-cobalt-chemicals-production-for-battery-applications.pdf>.)
- Terrafame Ltd., 2018, Annual and responsibility report 2017: Tuhkakyta, Finland, Terrafame Ltd., 143 p. (Accessed July 30, 2018, via <https://www.annualreport2017.terrafame.fi/download-center.html>.)
- Thomson Reuters, 2016, Eramet sees progress in nickel rescue plan, shares slide: Thomson Reuters, July 28. (Accessed December 15, 2017, at <https://www.reuters.com/article/eramet-nickel/eramet-sees-progress-in-nickel-rescue-plan-shares-slide-idUSL8N1AE3J8>.)
- Thomson Reuters, 2017a, Cuba sees 2017 nickel, cobalt sulfides output at 54,000 tonnes: Thomson Reuters, July 9. (Accessed August 9, 2017, at <https://www.reuters.com/article/us-cuba-metals-nickel/cuba-sees-2017-nickel-cobalt-sulfides-output-at-54500-tonnes-idUSKBN19U0PL>.)
- Thomson Reuters, 2017b, Freeport, China Moly agree to end talks on cobalt assets: Thomson Reuters, June 14. (Accessed May 9, 2018, at <https://www.reuters.com/article/us-freeport-mcmoran-cmoc/freeport-china-moly-agree-to-end-talks-on-cobalt-assets-idUSKBN1952V5>.)
- Umicore N.V./S.A., [undated], About us—Umicore cobalt & specialty materials: Brussels, Belgium, Umicore N.V./S.A. (Accessed April 25, 2019, at <http://csm.umicore.com/en/about-us/>.)
- Vale S.A., 2018, Form 20-F—For the fiscal year ended December 31, 2017: U.S. Securities and Exchange Commission, 192 p. (Accessed May 8, 2018, at http://www.vale.com/EN/investors/information-market/annual-reports/20f/20FDocs/Vale_20F_2017_i.PDF.)
- Vestel Elektronik Sanayi ve Ticaret AŞ, 2018, 2017 annual report: Istanbul, Turkey, Vestel Elektronik Sanayi ve Ticaret AŞ, 196 p. (Accessed May 8, 2020, via http://www.vestelinvestorrelations.com/en/_assets/pdf/AnnualReport_2017.pdf.)
- Votorantim S.A., 2018, 2017 report: Sao Paulo, Brazil, Votorantim S.A., 244 p. (Accessed May 8, 2020, at https://www.votorantim.com.br/relatorioanual/pdfs/relatorio_2017_en.pdf.)
- Wardell Armstrong International Ltd., 2013, Lundin Mining Corporation—NI 43-101 technical report on the Eagle Mine located in Upper Peninsula of Michigan, USA: Stoke-on-Trent, United Kingdom, Wardell Armstrong International Ltd., July 26, 241 p. (Accessed May 1, 2015, at <https://www.sedar.com/GetFile.do?lang=EN&docClass=24&issuerNo=00025806&issuerType=03&projectNo=02088155&docId=3373099>.)
- Wilson, Thomas, and Farchy, Jack, 2018, Mines linked to child labor are thriving in rush for car batteries: Bloomberg, February 19. (Accessed February 20, 2018, at <https://www.bloomberg.com/news/articles/2018-02-20/deadly-mines-linked-to-child-labor-thrive-in-rush-for-batteries>.)
- Xu, Aidong, 2016, China cobalt industry review: The Cobalt Conference, Cobalt Development Institute, Seoul, Republic of Korea, May 11–12, presentation, 22 p.
- Xu, Aidong, 2018, Hot issues in cobalt market: The Cobalt Conference, Cobalt Development Institute, Las Vegas, NV, May 23–24, presentation, 8 p.
- Zimplats Holdings Ltd., 2018a, 2018 integrated annual report: St. Peter Port, Guernsey [United Kingdom], Zimplats Holdings Ltd., 189 p. (Accessed April 30, 2019, at <https://www.zimplats.com/data/2018/09/ar2018.pdf>.)
- Zimplats Holdings Ltd., 2018b, Directors' report and condensed consolidated interim financial statements—Half year ended 31 December 2017: St. Peter Port, Guernsey [United Kingdom], Zimplats Holdings Ltd., February 27, 20 p. (Accessed April 30, 2019, at <https://www.zimplats.com/data/2018/02/DirectorsReportCondensedConsolidated-half-year-ended-31-December-2017.pdf>.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

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

Other

- Cobalt. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.
- Cobalt. *Mineral Profile*, British Geological Survey, 2009.
- Cobalt Institute (formerly known as the Cobalt Development Institute).
- CRU Group.
- DATAWEB, U.S. International Trade Commission.
- Defense Logistics Agency Strategic Materials.
- Federal Register, daily.

TABLE 1
SALIENT COBALT STATISTICS¹
(Metric tons, cobalt content, unless otherwise specified)

	2013	2014	2015	2016	2017
United States:					
Mine production ^e	(2)	120	760	690	640
Consumption:					
Reported	8,170	8,650	8,830	9,010	9,240
Apparent ³	8,660	8,710	10,300	11,500	8,910
Imports for consumption	10,400	11,300	11,400	12,800	11,900
Exports	3,850	4,500	3,830	4,160	5,730
Stocks, December 31:					
Industry ⁴	813	1,160	1,070	969	1,020
London Metal Exchange Ltd. (LME), U.S. warehouse	41	9	165	195	160
U.S. Government: ⁵					
Metal	301	301	301	301	302
Lithium-cobalt oxide					
gross weight	--	(6)	(6)	(6)	1
Lithium-nickel-cobalt-aluminum oxide					
do.	--	(6)	1	1	2
Cobalt alloys					
do.	--	--	--	--	(6)
Price, metal:					
U.S. spot ⁷					
dollars per pound	12.89	14.48	13.44	12.01	26.97
LME, cash ⁸					
do.	12.26	14.00	12.90	11.57	25.28
World:					
Production:					
Mine	103,000 ^r	113,000 ^r	117,000 ^r	109,000 ^r	120,000
Refinery	86,700	92,600 ^r	99,800	96,600	117,000
Stocks, December 31, LME ⁹	560	489	630	691	580

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

¹Table includes data available through July 22, 2019. Data are rounded to no more than three significant digits, except prices.

²Negligible.

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 Platts Metals Week.

⁸Annual 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.

⁹Stocks held in Asia, Europe, and the United States.

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

(Metric tons, cobalt content)

	2016	2017
Consumption by end use:		
Steels and other alloys, excludes superalloys ³	1,490	1,420
Superalloys	4,080	4,240
Cemented carbides ⁴	672	753
Chemical and ceramic uses	2,770	2,830
Total	9,010	9,240
Consumption by form:		
Chemical compounds, organic and inorganic ⁵	2,120	2,180
Metal	4,130	4,310
Purchased scrap	2,750	2,750
Total	9,010	9,240
Stocks, December 31: ⁶		
Chemical compounds, organic and inorganic ⁵	425	409
Metal	W	W
Purchased scrap	W	W
Total	969	1,020

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

¹Table includes data available through July 22, 2019. 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	2016			2017		
		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	10,800	10,800	\$267,000	9,530	9,530	\$465,000
Oxides and hydroxides	2822.00.0000	1,960	1,410	39,300	2,120	1,520	76,600
Other:							
Acetates	2915.29.3000	125	30	933 ^r	197	47	2,210
Carbonates	2836.99.1000	571	263	11,300	717	330	17,300
Chlorides	2827.39.6000	30	8	247	36	9	412
Sulfates	2833.29.1000	1,400	377	8,010	1,740	471	14,300
Total		14,800	12,800	327,000	14,300	11,900	576,000

^rRevised.

¹Table includes data available through June 21, 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 weight using the following percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; carbonates, 46%; chlorides, 25%; and sulfates, 27%.

⁴Customs value.

⁵Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

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

Country or locality	Metal ²			Oxides and hydroxides ³			Other forms ⁴			Total		
	Quantity (metric tons)		Value ⁶ (thousands)	Quantity (metric tons)		Value ⁶ (thousands)	Quantity (metric tons)		Value ⁶ (thousands)	Quantity (metric tons)		Value ⁶ (thousands)
	Gross weight	Cobalt content ⁵		Gross weight	Cobalt content ⁵		Gross weight	Cobalt content ⁵		Gross weight	Cobalt content ⁵	
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	40,500 ^r	(7)	(7)	19	--	--	--	1,750	1,750	40,600 ^r
Macao	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
2017:												
Australia	186	186	6,000	--	--	--	--	--	--	186	186	6,000
Belgium	11	11	799	543	391	22,200	25	7	278	578	408	23,300
Brazil	29	29	1,840	--	--	--	229	70	1,750	258	98	3,590
Canada	1,600	1,600	69,300	1	(7)	23	11	3	11	1,610	1,600	69,300
China	729	729	35,100	443	319	15,400	773	240	10,900	1,940	1,290	61,400
Finland	507	507	24,200	398	287	13,000	1,390	460	18,500	2,300	1,250	55,700
France	34	34	1,670	--	--	--	--	--	--	34	34	1,670
Germany	40	40	2,520	5	4	255	(7)	(7)	3	45	43	2,780
Hong Kong	89	89	4,140	--	--	--	--	--	--	89	89	4,140
Japan	1,420	1,420	73,300	20	15	631	1	(7)	10	1,440	1,430	73,900
Korea, Republic of	(7)	(7)	14	40	29	1,160	--	--	--	40	29	1,180
Madagascar	1,070	1,070	54,000	--	--	--	--	--	--	1,070	1,070	54,000
Morocco	178	178	8,410	--	--	--	--	--	--	178	178	8,410
Norway	2,560	2,560	136,000	(7)	(7)	5	--	--	--	2,560	2,560	136,000

See footnotes at end of table.

TABLE 4—Continued
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 ⁵	Value ⁶ (thousands)	Gross weight	Cobalt content ⁵	Value ⁶ (thousands)	Gross weight	Cobalt content ⁵	Value ⁶ (thousands)	Gross weight	Cobalt content ⁵	Value ⁶ (thousands)
2017:—Continued												
Russia	408	408	\$19,000	--	--	--	(7)	(7)	\$6	408	408	\$19,000
South Africa	288	288	10,900	2	1	\$33	1	1	38	291	289	10,900
Switzerland	36	36	1,270	--	--	--	--	--	--	36	36	1,270
United Kingdom	32	32	1,400	663	477	23,900	228	67	2,320	923	576	27,600
Zambia	315	315	14,700	--	--	--	--	--	--	315	315	14,700
Other	5	5	209	(7)	(7)	11	31	10	350	36	15	570
Total	9,530	9,530	465,000	2,120	1,520	76,600	2,690	857	34,200	14,300	11,900	576,000

¹Revised. -- Zero.

²Table includes data available through June 21, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

³Unwrought 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.

⁴HTS code 2822.00.0000.

⁵Cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates under HTS codes 2827.39.6000, 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)
2016:	3,980	\$78,000	134	\$1,380	314	\$1,580	1	\$17	4,160	\$81,000
2017:										
Argentina	11	489	--	--	--	--	--	--	11	489
Australia	137	4,370	--	--	--	--	--	--	137	4,370
Austria	50	490	--	--	--	--	--	--	50	490
Belgium	109	2,920	162	1,430	66	678	--	--	241	5,020
Brazil	54	2,060	11	497	--	--	--	--	62	2,560
Canada	2,270	19,400	2	83	--	--	--	--	2,270	19,400
China	55	2,920	1	60	--	--	(9)	3	56	2,980
France	671	13,800	(9)	4	--	--	--	--	671	13,800
Germany	220	10,900	1	43	--	--	--	--	220	10,900
Hong Kong	25	708	(9)	27	--	--	--	--	26	735
India	53	2,520	(9)	6	133	1,740	--	--	85	4,260
Indonesia	8	472	--	--	--	--	--	--	8	472
Ireland	947	20,700	--	--	--	--	--	--	947	20,700
Italy	17	1,060	--	--	--	--	(9)	6	17	1,060
Japan	151	8,440	(9)	4	--	--	--	--	151	8,450
Korea, Republic of	70	3,810	(9)	9	--	--	--	--	70	3,820
Malaysia	5	330	(9)	6	--	--	--	--	5	337
Mexico	3	223	21	913	--	--	(9)	4	18	1,140
Netherlands	87	4,810	--	--	--	--	--	--	87	4,810
Singapore	35	2,460	--	--	--	--	--	--	35	2,460
South Africa	5	276	--	--	--	--	--	--	5	276
Switzerland	33	851	--	--	--	--	--	--	33	851
Taiwan	46	996	--	--	--	--	2	23	46	1,020
Tunisia	12	373	--	--	--	--	--	--	12	373
Turkey	19	592	--	--	--	--	--	--	20	592
United Arab Emirates	16	433	--	--	--	--	--	--	16	433
United Kingdom	410	9,660	--	--	--	--	(9)	3	410	9,660
Other	15	1,160	(9)	5	--	--	4	55	16	1,220
Total	5,540	117,000	200	3,090	199	2,420	6	94	5,730	123,000

¹Revised. -- Zero.

²Table includes data available through August 23, 2018. 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 Harmonized Tariff Schedule of the United States (HTS) codes 8105.20.0000 and 8105.30.0000.

⁵HTS code 2822.00.0000.

⁶HTS code 2915.29.3000.

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 1/2 unit.

Source: U.S. Census Bureau.

TABLE 6
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2017^{1,2}

(Metric tons, cobalt content)

Country or locality	Capacity
Australia	6,700
Belgium	1,600 ^e
Brazil	3,000 ^e
Canada ³	9,020
China	100,000 ^e
Congo (Kinshasa)	9,050 ^e
Finland ⁴	16,500 ^e
France	500
India	2,060 ^e
Japan	5,300 ^e
Madagascar	5,600
Mexico	1,700
Morocco	2,250
Norway	5,200
Russia	7,520 ^e
South Africa	1,500 ^e
Uganda	720
Zambia	9,600
Total	188,000 ^e

^eEstimated.

¹Table includes data available through February 15, 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 because Vale S.A.'s Long Harbour refinery began production in 2017.

⁴Revised upward to include estimated capacity for PJSC MMC Norilsk Nickel's Harjavalta refinery.

TABLE 7
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2018–2022^{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	Belgium	Olen Umicore N.V./S.A.	Upgrade and expand existing refinery	Cobalt	Intermediates and scrap	3,000 ^{e,3}	Cobalt metal powders, oxides, and salts.
2018	Congo (Kinshasa)	Kipushi Cobalt Copper Tailings Soludo-Lambert Mining SAS (Cape Lambert Resources Ltd. and Paragon Mining SARL)	Upgrade existing beneficiation plant	do.	Copper-cobalt tailings	NA	Copper-cobalt concentrate.
2018	do.	NA Chengtung Cobalt Resource New Material Co., Ltd. (Chengtung Mining Group Co., Ltd. and Shenzhen Chengtung Rare Materials Technology Co., Ltd.)	New refinery	Copper	Copper-cobalt concentrate	3,500	Cobalt hydroxide.
2018	do.	NA Metal Mines sprl (Nanjing Hanrui Cobalt Co. Ltd.)	do.	Cobalt	Cobalt ore and concentrate	2,000	Cobalt metal.
2018	do.	NA La Miniere de Kasombo Sprl (MIKAS) [Congo Dongfang International Mining SPRL (Zhejiang Huayou Cobalt Co., Ltd.) and La Générale des Carrières et des Mines SARL (Gécamines)]	New processing plant	Copper	Copper-cobalt concentrate	4,000	Cobalt hydroxide.
2018	do.	PE 527 La Miniere de Kasombo Sprl (MIKAS) [Congo Dongfang International Mining SPRL (Zhejiang Huayou Cobalt Co., Ltd.) and La Générale des Carrières et des Mines SARL (Gécamines)]	New mine	do.	Copper-cobalt ore	NA	NA.
2018	do.	SMCO Cobalt, phase 1 Shituru Mining Corp. (Pengxin International Mining Co., Ltd.)	New processing plant	Cobalt	Copper-cobalt concentrate	3,000	Cobalt hydroxide.

See footnotes at end of table.

TABLE 7—Continued
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2018–2022^{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	Congo (Kinshasa)	WOL ⁴ Project, Cobalt Debotlenecking Katanga Mining Ltd., La Générale des Carrières et des Mines SARL (Gécamines), and La Société Immobilière du Congo	Upgrade existing beneficiation and cobalt processing plants	Copper	Copper-cobalt-oxide and sulfide ore	34,000 ^{e,3}	Cobalt hydroxide.
2018	Zambia	Chambishi Southeast Mine NFC Africa Mining Plc (China Nonferrous Mining Corp. Ltd. and ZCCM Investment Holdings Plc)	New mine and processing plant	do.	Copper-cobalt ore	1,000	Do.
2019 ^e	Australia	Rocklands Group Copper, stage 1 CuDeco Ltd.	Commission cobalt-pyrite circuit at existing operation	do.	Copper-cobalt-gold oxide and sulfide ore	730 ^{e,5}	Cobaltic-pyrite concentrate.
2019	do.	Savannah North Panoramic Resources Ltd.	New mine	Nickel	Nickel-copper-cobalt sulfide ore	800 ⁶	Nickel-copper-cobalt concentrate.
2019	Congo (Kinshasa)	COMMUS (Kolwezi Copper Mine), phase 2 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.]	Add refinery to existing mine	Copper	Copper-cobalt ore	3,000	Cobalt compound.
2019	do.	Huachin CNMC Huachin Mabende Mining SA [Sino-Metals Leach Zambia Ltd. (China Nonferrous Mining Corp. Ltd.) and Huachin SPRL]	Add cobalt recovery to existing mine and refinery	do.	do.	2,000	Cobalt hydroxide.
2019	do.	Kamoya Wanbao Mining Ltd.	New processing plant	do.	Copper-cobalt concentrate	4,000	Do.
2019	do.	Metalkol RTR [Roan Tailings Reclamation (formerly Kolwezi tailings)], phase 1 Eurasian Resources Group B.V., La Générale des Carrières et des Mines SARL (Gécamines), and Government of Congo (Kinshasa)	New refinery	do.	Copper-cobalt tailings	14,000	Do.

See footnotes at end of table.

TABLE 7—Continued
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2018–2022^{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
2019	Congo (Kinshasa)	Mutushi Chemaf SARL	New refinery	Copper	Copper-cobalt tailings	16,000	Cobalt hydroxide.
2019	South Africa	Nickel Purification Plant Thakadu Battery Materials Pty. Ltd. and Lonmin plc	Add nickel purification plant to existing base metal refinery	Nickel	Crude nickel sulfate	NA	Do.
2019	Zambia	Kitwe, phase 1 Tianjin Maolian Science & Technology Co., Ltd.	New processing plant	Copper	Copper-cobalt slag	3,000	Do.
2019	do.	Munali nickel mine Consolidated Nickel Mines plc	Restart production from existing mine	Nickel	Nickel-copper-cobalt-platinum-group-metals sulfide ore	200 ⁵	Cobalt in nickel concentrate.
2020	Australia	AFC Nickel Sulphate Plant Alpha Fine Chemicals Ltd.	New refinery	do.	Nickel-cobalt hydroxide	100 ^e	Cobalt carbonate.
2020	Canada	Dumont, phase 1 Royal Nickel Corp.	New mine and beneficiation plant	do.	Nickel-cobalt sulfide ore	1,000	Nickel-cobalt concentrate.
2020	China	Fangchenggang Plant Jinchuan Group Co. Ltd.	New refinery	do.	NA	3,000	NA.
2020	Congo (Kinshasa)	Cobalt Recycling System of the Blister Copper Smelting Project Lualaba Copper Smelter SAS [Huachin Metal Leach SA (China Nonferrous Mining Corp. Ltd.) and Yunnan & Hongkong Metal Co., Ltd. (Yunnan Copper Industry Group Co., Ltd.)]	New smelter	Copper	Copper-cobalt concentrate	2,000	Copper-cobalt alloy.
2020	do.	NA Metal Mines sprl (Nanjing Hanrui Cobalt Co. Ltd.)	Expand existing refinery	Cobalt	Cobalt ore and concentrate	5,000 ³	Cobalt metal.
2020	do.	Pumpi-Kamassani La Minière de Kalukundi (LAMIKAL) [Wanbao Mining Ltd., Groupe Managem, and Congo Stars Mining Sarl (Costamin)]	New mine and smelter	Copper	Copper-cobalt ore	5,000	Copper-cobalt alloy.
2020 ^e	do.	SMCO Cobalt, phase 2 Shituru Mining Corp. (Pengxin International Mining Co., Ltd.)	Expand existing processing plant	Cobalt	Copper-cobalt concentrate	7,000 ³	Cobalt hydroxide.

See footnotes at end of table.

TABLE 7—Continued
 COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2018–2022^{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
2020	Finland	Battery chemicals plant Terraframe Ltd. [Terraframe Group Ltd. (Government of Finland), Galena Asset Management S.A. (Trafigura Group), and Sampo plc]	Add refinery to existing operation	Nickel	Nickel-cobalt sulfide	1,000 ^e	Cobalt sulfate.
2020	do.	Kevitsa Boliden AB	Expand existing mine and beneficiation plant	do.	Nickel-copper-cobalt-platinum-group-metals-gold sulfide ore	760 ^{e,3}	Nickel-cobalt-platinum-group-metals concentrate.
2020	United States (Idaho)	Idaho Cobalt eCobalt Solutions Inc.	New mine and beneficiation plant	Cobalt	Stratiform cobalt-copper-gold ore	1,500 ⁵	Cobalt concentrate.
2020	United States (Michigan)	Eagle East Eagle Mine LLC (Lundin Mining Corp.)	New mine	Copper-nickel	Nickel-copper sulfide ore	NA	Cobalt in nickel concentrate.
2020 ^e	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	Australia	Sunrise (previously named Syerston) Clean TeQ Metals Pty Ltd. (Clean TeQ Holdings Ltd.)	New mine and refinery	Nickel	Nickel-cobalt laterite ore	7,000	Cobalt sulfate.
2021	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.
2021	do.	Voisey's Bay Mine Expansion Vale Canada Ltd. (Vale S.A.)	Expand existing mine	Nickel	Nickel-cobalt sulfide ore	2,600 ⁷	Nickel-copper-cobalt concentrate.
2021	Congo (Kinshasa)	Ruashi Ruashi Mining SPRL [Metorex (Proprietary) Ltd. (Jinchuan Group International Resources Co., Ltd.) and La Générale des Carrières et des Mines SARL (Gécamines)]	Expand existing mine and refinery	Copper	Copper-cobalt ore	10,000 ³	Cobalt hydroxide.
2021	Zambia	Kitwe-Uchi Copper Tree Minerals Ltd. (Horizon Mining Ltd. and ZCCM Investment Holdings Plc)	New processing plant	do.	Copper-cobalt tailings	1,200	Do.

See footnotes at end of table.

TABLE 7—Continued
 COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2018–2022^{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
2022	Congo (Kinshasa)	Musonoi Ruashi Mining SPRL [Metorex (Proprietary) Ltd. (Jinchuan Group International Resources Co., Ltd.) and La Générale des Carrières et des Mines SARL (Gécamines)]	New mine and beneficiation plant	Copper	Copper-cobalt oxide ore and copper-cobalt sulfide ore	7,800 ⁵	Copper-cobalt oxide ore and copper-cobalt sulfide concentrate.

¹Estimated. Do., do. Ditto. NA Not available.

²Estimated data are rounded to no more than three significant digits.

³Projects in feasibility or later stages of development in 2017. Actual startup dates may be postponed owing to economic or other factors. Additional projects might produce cobalt by 2022, but not enough information was available to include them.

⁴Total capacity following expansion.

⁵WOL whole ore leach.

⁶Average production.

⁷Total combined average production from Savannah and Savannah North Mines.

⁸Total average production following expansion.

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

(Metric tons, cobalt content)

Country or locality ³	2013	2014	2015	2016	2017
Australia ⁴	6,400 ^r	6,201 ^r	5,721 ^r	5,140 ^r	5,034
Botswana ⁵	248	196	316	248 ^r	--
Brazil	3,500	3,828	2,771 ^r	200 ^{r, c}	-- ^e
Canada ⁶	4,005	3,907	4,339	4,126 ^r	3,866 ^p
China ^e	2,600	2,800	3,000	3,100	3,100
Congo (Kinshasa) ^{e, 7}	56,000	62,000	66,000	63,000 ^r	73,000
Cuba ^{e, 8}	4,000	3,700	4,300	5,100	5,000
Finland ^{e, 9}	750	770	440	690	1,000
Indonesia ^{e, 10}	1,700	1,300	1,300	1,200	1,200
Madagascar ^{e, 11}	2,400	3,400	4,000	3,800	3,500
Mexico ^e	--	--	--	980	1,000
Morocco ^{e, 12}	2,000	2,150	2,250	2,400	2,200
New Caledonia ^{e, 13}	3,190	4,040	3,640 ^r	3,390	2,780
Papua New Guinea ¹⁴	1,013	2,134	2,505	2,191	3,308
Philippines ^{e, 15}	2,800	4,600	4,300	4,100	4,600
Russia ^{e, 16}	6,300	6,300	6,200	5,500	5,900
South Africa ^e	3,000	3,000	2,900	2,300	2,300
Turkey ¹⁴	--	--	NA	100 ^e	220
United States ^{e, 16, 17}	(18)	120	760	690	640
Vietnam ¹⁶	25 ^e	223	277	134	--
Zambia ^e	2,500 ^r	2,300 ^r	1,700 ^r	600 ^r	1,000
Zimbabwe ¹⁹	319	358	355	409	445
Total	103,000 ^r	113,000 ^r	117,000 ^r	109,000 ^r	120,000

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

¹Table includes data available through October 15, 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 listed, Spain may have produced cobalt, but available information was inadequate to make reliable estimates of output. Other copper-, iron (pyrite)-, nickel-, platinum-, or zinc-producing 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 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.

⁹Excludes low-grade cobalt-nickel concentrates that were stockpiled until a marketable product was developed.

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

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

¹²Cobalt content of concentrate estimated from reported gross weight.

¹³Cobalt 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.

¹⁴Cobalt content of nickel-cobalt hydroxide.

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

¹⁶Cobalt content of concentrates.

¹⁷Negligible production prior to 2014.

¹⁸Negligible.

¹⁹Production 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	2013	2014	2015	2016	2017
Australia, metal powder and oxide hydroxide ³	4,981	5,419	5,150	3,350 ^{e,4}	3,000
Belgium, metal powder, oxide, hydroxide ^{e,5}	1,400 ^r	1,300 ^r	1,500 ^r	1,500 ^r	1,600
Brazil, metal ³	1,871 ⁶	1,350 ⁶	1,300	400	46
Canada, metal, metal powder, oxide	5,602	5,491	6,126	6,302 ^r	6,355 ^p
China, metal, metal powder, oxide, salts ^{e,7}	40,100 ^r	43,800 ^r	53,500 ^r	49,900 ^r	75,000
Congo (Kinshasa), metal ⁸	2,777	2,859	3,141	50 ^r	120
Finland, metal powder and salts ⁹	10,798	12,551	9,615	12,393	12,222
France, chloride ³	308	219	133	119	277
India, metal and salts ³	295	100	150	100	100
Japan, metal ³	2,747	3,654	4,259	4,305	4,159
Madagascar, metal powder	2,083	2,915	3,464	3,273	3,053
Mexico, metal	--	--	--	419	420 ^c
Morocco, metal	1,353	1,391	1,982	2,081	1,924
Norway, metal ¹⁰	3,348	3,600	3,100	3,500	3,500
Russia, metal ³	2,368	2,302	2,040	3,092	2,077
South Africa, metal powder and sulfate ³	1,294 ¹¹	1,332 ¹¹	1,300	1,101	1,062
Uganda, metal ³	376	--	--	--	--
Zambia, metal ³	5,000	4,317	2,997	4,725	2,520
Total	86,700	92,600 ^r	99,800	96,600	117,000

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

¹Table includes data available through October 11, 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 Institute (formerly Cobalt Development Institute), except as noted.

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

⁵Production estimate reported by Darton Commodities Ltd.

⁶Production reported by National Department of Mineral Production.

⁷Production from domestic and imported ores, concentrates, and intermediate materials.

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

⁹Production reported by the Geological Survey of Finland.

¹⁰Data were reported by the Geological Survey of Norway for 2013 and Glencore plc for 2014–17.

¹¹Production reported by the Department of Mineral Resources.