



2015 Minerals Yearbook

COBALT [ADVANCE RELEASE]

COBALT

By Kim B. Shedd

Domestic survey data and tables were prepared by Annie Hwang, statistical assistant, and the world production and projects tables were prepared by Lisa D. Miller,¹ and Glenn J. Wallace, international data coordinators.

In 2015, world production of refined cobalt increased by 5% to reach a record level of 97,400 metric tons (t) (table 9). A large increase in production from China more than balanced out significant decreases in production from Canada, Finland, and Zambia. The United States did not refine cobalt in 2015. World mine production increased by 3% to reach a record level of 126,000 t (table 8). Congo (Kinshasa) remained the leading producer of mined cobalt, supplying one-half of world production, followed by China, Canada, Russia, and Australia. Cobalt was mined in the United States as a byproduct of nickel and copper in Michigan, and a negligible amount of byproduct cobalt was produced in an intermediate product from the mining and refining of platinum-group-metals (PGM) ore in Montana. No cobalt has been sold from the National Defense Stockpile (NDS) since 2009.

According to the Cobalt Development Institute (2016a), preliminary data indicate that in 2015, world apparent consumption of cobalt increased by about 7,000 t, or about 8%, to approximately 89,000 t. Cobalt prices generally trended downward during the year, resulting in annual averages less than those of 2014. Salient U.S. and world cobalt statistics for 2011–15 are listed in table 1.

Cobalt is a metal used in numerous diverse commercial, industrial, and military applications. Globally, the leading use of cobalt is in rechargeable battery electrodes. Superalloys, which are used to make parts for gas turbine engines, are another major use for cobalt. Other metallurgical uses for cobalt include cemented carbides (also called hardmetals) and diamond tools, controlled-expansion and corrosion- and wear-resistant alloys, high-speed and maraging steels, and magnets. With regard to other chemical uses, cobalt is used to make animal feed additives; catalysts for chemical, petroleum, and other industries; drying agents for inks, paints, and varnishes; dyes and pigments; glass decolorizers; ground coats for porcelain enamels; humidity indicators; magnetic recording media; rubber adhesion promoters for steel-belted radial tires; and vitamin B12.

Legislation and Government Programs

Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt during 2015. The program under which cobalt metal sales were authorized expired in 2011 and had not been reauthorized. DLA Strategic Materials had a contract with a domestic producer to supply the agency with cobalt-bearing lithium-ion battery precursor materials. During the calendar year, DLA Strategic Materials purchased 150 kilograms (kg), gross weight, of lithium-cobalt oxide (LCO) and 610 kg, gross weight, of lithium-nickel-cobalt-aluminum oxide (NCA). The

annual materials plan for fiscal year 2016 (October 1, 2015, through September 30, 2016), which represented the maximum amounts of materials that could be bought or sold during the year, provided for acquisitions of 300 kg, gross weight, of LCO and 1,080 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, 2015; U.S. Department of Defense, 2016, p. 10, 35).

Production

Lundin Mining Corp. (Toronto, Ontario, Canada) produced copper and nickel concentrates from the Eagle nickel-copper mine northwest of Marquette, MI, and mill in Humboldt Township. In 2015, Eagle produced nickel concentrate containing 27,167 t of nickel and an estimated 760 t of cobalt, based on reported quarterly nickel production and ore grades and a forecast of annual cobalt ore grade from the production schedule. The concentrate was sent by rail to smelters in North America or to ports for shipment overseas (Lundin Mining Corp., 2016a, p. 24; 2016b, p. 19).

Stillwater Mining Co.'s PGM mining and refining operations in southeastern Montana produced negligible amounts of cobalt in nickel sulfate, which it sold to other companies (Stillwater Mining Co., 2016, p. 20).

In November, the final environmental impact statement (EIS) was completed for PolyMet Mining Corp.'s NorthMet project and the U.S. Forest Service issued a draft record of decision on a land exchange for the project. In early 2016, the Minnesota Department of Natural Resources validated the EIS and Polymet shifted its focus towards permitting. Phase 1 of the project comprised open pit mining of the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota and production of copper and nickel concentrates. Polymet expected construction and rampup to commercial production to take about 24 months after receiving the permits (table 7) (PolyMet Mining Corp., 2016, p. 14–15).

Formation Metals Inc.'s environmentally permitted Idaho Cobalt project comprised an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County and a hydrometallurgical plant to refine the concentrates in a location to be determined. During the year, Formation completed a preliminary economic analysis on a process to produce an average of approximately 1,260 metric tons per year (t/yr) of cobalt in sulfate for the battery sector and began bench-scale test production of crystalline cobalt sulfate from the project's ore. The company planned to complete a definitive feasibility study, secure offtake and other sale agreements, and seek strategic partnerships to develop the

¹Deceased.

project. Once financing was completed, Formation planned to begin underground mine development and to construct the beneficiation and hydrometallurgical plants. Initial production was expected to take place about 13 months after commencing underground development (table 7) (Formation Metals Inc., 2016, p. 2, 12, 14, 21, 26).

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

Cobalt was recovered from secondary (scrap) materials by subsidiaries of n.v. Umicore, s.a. (Brussels, Belgium) and Plansee Group (Reutte, Austria). The Umicore Specialty Materials Recycling plant in Wickliffe, OH, processed secondary materials such as superalloy scrap and made chemicals for the catalyst and petrochemical refining industries. The Umicore Specialty Chemicals plant in Arab, AL, recycled spent catalysts for its customers. Plansee Group's Global Tungsten & Powders Corp. (GTP) in Towanda, PA, recovered an intermediate cobalt chemical compound as a byproduct of tungsten recovery from cemented carbide scrap. GTP had a partnership with Umicore whereby Umicore would toll process GTP's intermediate cobalt compound to cobalt metal powder, starting in 2015 (Global Tungsten & Powders Corp., 2014; n.v. Umicore, s.a., 2015a, p. 34, 77; undated).

Consumption

U.S. reported consumption of cobalt in 2015 was 3% more than that of 2014. Metallurgical industries used slightly less cobalt than they did in 2014, and cobalt consumption for chemical uses was 16% more than that of 2014. 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 2015, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 18% more than that in 2014 (table 1). The increase was a result of increases in net imports and scrap consumption and a drawdown of industry stocks in 2015 compared to those in 2014.

Prices

The annual average U.S. spot price for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, was 7% less than that of 2014 (table 1). The overall price trend was downward, although prices fluctuated during the year. The highest price range was \$13.90 to \$15.50 per pound during

July and in early August, and the lowest price range was \$9.50 to \$10.50 per pound during the last 3 weeks of the year.

Trends in Platts' prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were similar to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was \$13.06 per pound, and the annual average of weekly prices for Russian cobalt was \$13.02 per pound.

In 2015, the London Metal Exchange Ltd. (LME) added coarse-grained metal powder to its cobalt contract. Prior to this addition, the contract included briquettes, broken or cut cathodes, ingots, and rounds. At yearend, the number of producers whose cobalt was approved for delivery on the LME cobalt futures contract remained at 15, and the deliverable shapes of the approved brands were cathodes, ingots, and rounds. Sherritt International Corp. (2016a, p. 9) reported that the amount of cobalt traded on the LME in 2015 (8,688 t) represented only 20% of global refined cobalt metal production and 9.5% of global refined production of cobalt metal and chemicals. Considering that base-metal contracts on the LME experience trading volumes of 50 or more times their production, the LME cobalt contract is still in the early stage of acceptance as a primary pricing mechanism. The annual average mean of cash buyer and cash seller prices and yearend LME inventory levels are listed in table 1 (London Metal Exchange Ltd., The, undated a, b).

Electrolytic cobalt was also traded on China's Fanya Metal Exchange. Before Fanya's Web site was suspended in November, the exchange held about 23 t of cobalt (Anna Xu, 2016).

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 2015, net import reliance as a percentage of apparent consumption was 73%. Because U.S. cobalt mine production was exported to be refined, this indicates that 73% of U.S. cobalt supply was from imports and stock releases of refined cobalt and 27% was from domestic or imported scrap.

In 2015, the United States imported 11,400 t of cobalt contained in metal and chemical compounds, valued at \$334 million, essentially unchanged from the revised quantity of contained cobalt imported in 2014 (tables 3, 4). On the basis of cobalt content, 11 countries supplied 89% of U.S. imports. China was the leading supplier, followed by Norway, Japan, Finland, Madagascar, Russia, Australia, South Africa, the United Kingdom, Morocco, and Belgium. The United States also imported unwrought cobalt alloys (1,250 t, gross weight, valued at \$39.7 million), cobalt waste and scrap (812 t, gross weight, valued at \$12.1 million), and wrought cobalt and cobalt articles (211 t, gross weight, valued at \$21.8 million).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 3,830 t, valued at \$91.1 million; 15% less by

weight than the 4,500 t exported in 2014. As listed in table 5, on the basis of cobalt content, the leading destinations for these exports were Canada, France, Ireland, Belgium, the United Kingdom, Germany, and Japan. The United States also exported 1,890 t, gross weight, of wrought metal and cobalt articles valued at \$108 million.

World Review

World cobalt mine and refinery production each increased in 2015 compared with production in 2014. On the basis of tons of contained cobalt, China had the largest increase in refinery production and Congo (Kinshasa), Cuba, Madagascar, and the United States had the largest increases in mine production.

Cobalt was produced as a byproduct of copper, nickel, and other metals, and as a primary product. 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.

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

The following review by country focuses on operations that produced cobalt in 2015. Expansions to those operations, operation restarts, and greenfield projects that were forecast to begin producing between 2016 and 2020 are listed in table 7.

Australia.—In 2015, Western Australian cobalt mine production, which is a byproduct of the State's nickel industry, was estimated to be similar to that of 2014 (table 8). Australian production of refined cobalt, which included production from imported lateritic ore, decreased by 5% (table 9).

The Palmer Nickel and Cobalt Refinery (owned by Australian businessman Clive Palmer, operated by Queensland Nickel Pty. Ltd.) in Townsville, Queensland, produced 1,850 t of refined cobalt as cobalt oxide hydroxide; 27% less than the 2,519 t produced in 2014. Darton Commodities Ltd. (2016, p. 14) attributed the decrease to reduced feed supply and lower cobalt recoveries. In recent years, the refinery has processed lateritic ore from the Brolga Mine and the Dingo Dam mining lease of Metallica Minerals Ltd.'s Lucky Break project, both in Queensland; lateritic ore imported from New Caledonia and the Philippines; and an intermediate cobalt compound from Vale S.A.'s New Caledonia operation. In early 2016, Queensland Nickel entered voluntary administration as a result of financial problems owing to the low nickel price and the refinery temporarily ceased operations in March 2016 owing to a shortage of ore supply (Cobalt Development Institute, 2016a; Department of Natural Resources and Mines, 2016, p. 41–42; Westbrook, 2016).

BHP Billiton Plc's Nickel West operations in Western Australia comprised nickel sulfide mines; concentrators, which processed ores mined by BHP Billiton and other companies; the Kalgoorlie smelter, where nickel matte was produced; and the Kwinana nickel refinery, which produced cobalt in intermediate nickel-cobalt sulfide (BHP Billiton Plc, 2016, p. 234–235).

Following the sale of the Cosmos Mine to Western Areas Ltd. in mid-2015, Glencore plc had one remaining nickel asset in Western Australia—Minara Resources Ltd.'s Murrin Murrin nickel-cobalt laterite mining and pressure-acid-leaching operation. In 2015, Murrin Murrin produced 3,300 t of cobalt metal (2,900 t in 2014); approximately 500 t of this 2015 production was from third-party feed (200 t in 2014) (Glencore plc, 2016, p. 55, 189, 196).

First Quantum Minerals Ltd. (Vancouver, British Columbia, Canada) produced intermediate nickel-cobalt hydroxide from its Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant in Western Australia. In 2015, the plant produced 26,668 t of nickel and, based on the hydroxide containing 40% nickel and 1.4% cobalt, an estimated 920 t of cobalt (36,445 t of nickel and an estimated 1,260 t of cobalt in 2014). The decrease in production was attributed to a structural failure in an atmospheric leaching tank, which disrupted production in December 2014. The leach circuit was recommissioned in July, but the plant operated at reduced capacity for the remainder of the year while refurbishment efforts took place. Most of Ravensthorpe's hydroxide reportedly was sent to China, with lesser amounts sold to Brazil and India (Metal Bulletin Daily, 2015b; First Quantum Minerals Ltd., 2016, p. 26, 36).

Panoramic Resources Ltd. produced concentrates containing 465 t of cobalt (436 t in 2014) from its Savannah underground nickel-copper sulfide mine operation in Western Australia. The concentrates were shipped to Jinchuan Group Co. Ltd.'s operations in China under a long-term offtake agreement. In early 2016, Panoramic announced that it would place the mine on care-and-maintenance status to preserve the resource until nickel prices improved (Panoramic Resources Ltd., 2015, p. 5, 21; 2016, p. 3–4).

Mincor Resources NL mined nickel-copper sulfide ores from its South Kambalda operations in Western Australia. All of the ore was toll processed by BHP Billiton at its Nickel West Kambalda concentrator and the resulting concentrate was sold to BHP Billiton under long-term agreements. In 2015, Mincor produced nickel concentrate from its Mariners and Miitel Mines and sold concentrate containing 96 t of cobalt (191 t in 2014). The company planned to cease mining at the end of January 2016 and implement a care-and-maintenance program in response to continuing decreases in the price of nickel (Mincor Resources NL, 2015, p. 2; 2016).

Belgium.—According to the Cobalt Development Institute (2016a), Umicore's 2015 cobalt refinery production increased by 8% to 6,306 t of contained cobalt from 5,850 t produced in 2014. Umicore converted various cobalt materials into a wide range of chemicals and metal powders at refineries in Olen, Belgium, and Ganzhou, China. In September 2015, Umicore announced that it planned to upgrade its refinery in Olen to increase cobalt production, increase its ability to recycle cobalt- and nickel-bearing residues, and improve efficiency. The company also had cobalt processing plants, which made specialty chemicals or metal powders from refined cobalt or scrap, in Arab, AL, LaVergne, TN, and Wickliffe, OH; Bruges, Belgium; Fort Saskatchewan, Alberta, Canada; Jiangmen and Shanghai, China; and Cheonan, Republic of Korea (n.v. Umicore, s.a., 2015b).

Botswana.—In April, PJSC MMC Norilsk Nickel (Norilsk) completed the sale of its 85% share in Tati Nickel Mining Co. Pty. Ltd. to BCL Ltd. Tati Nickel (15% Government of Botswana) mined the Phoenix open pit and produced nickel-copper sulfide concentrates containing cobalt, which were smelted to high-grade matte by BCL in Botswana. BCL also smelted concentrate from its Selebi-Phikwe operation in Botswana (PJSC MMC Norilsk Nickel, 2016b, p. 69, 206).

Brazil.—Votorantim Metais S.A. produced cobalt cathode at its Sao Miguel Paulista, Sao Paulo State, refinery mainly from lateritic nickel-cobalt ore mined from Niquelandia, Goias State. In January 2016, Votorantim announced that because of market conditions it would temporarily suspend its nickel operations. The company reportedly planned to shut down mining operations at Niquelandia in February and cease processing at Niquelandia and refining at Sao Miguel Paulista in May (Metal Bulletin Daily, 2016).

During the first half of 2015, Mirabela Nickel Ltd. produced 149 t of cobalt in nickel sulfide concentrate from its Santa Rita open pit mine and concentrator in Bahia State. In September, the company was placed under voluntary administration and production results were not released for the second half of the year. Production was cut back beginning in late October to reduce operating costs in response to the low nickel price, and the company planned to place the mine on care-and-maintenance status in early 2016. The concentrate was sold to Norilsk Nickel Harjavalta Oy and an international trading firm (Mirabela Nickel Ltd., 2015, 2016).

Canada.—Vale's global cobalt production was 4,533 t in 2015, 21% more than the 3,743 t produced in 2014. Vale produced 1,448 t (1,362 t in 2014) of refined cobalt metal at its Port Colborne, Ontario, refinery; 2,926 t (1,124 t in 2014) of cobalt in a cobalt intermediate product at its nickel operations in Canada and New Caledonia; and 159 t (1,257 t in 2014) of cobalt contained in other intermediate products such as nickel concentrates. Vale's cobalt originated from company-owned nickel sulfide mines at Sudbury, Ontario, Thompson, Manitoba, and Voisey's Bay in northeastern Labrador; from a company-owned nickel laterite mine in New Caledonia; and from purchased feedstock materials. Vale reported that 751 t (833 t in 2014) of cobalt came from Ontario, 365 t (489 t in 2014) came from Manitoba, 849 t (952 t in 2014) came from Voisey's Bay, 2,391 t (1,384 t in 2014) came from New Caledonia, and 177 t (84 t in 2014) came from external sources (Vale S.A., 2015, p. 45; 2016a, p. 48–49).

The decrease in Vale's cobalt production from Voisey's Bay was attributed to a shift in the processing location of that mine's nickel concentrate. During 2015, most of the Voisey's Bay nickel concentrate was shipped to Vale's operations at Sudbury and Thompson for smelting and refining. Some Voisey's Bay concentrate was sent to Vale's hydrometallurgical refinery in Long Harbour, Newfoundland and Labrador, where it was blended with nickel matte from PT Vale Indonesia Tbk and refined. In the fourth quarter of 2015, a greater portion of the nickel concentrate from Voisey's Bay was sent to the Long Harbour refinery, where cobalt production had not yet commenced (Vale S.A., 2016a, p. 37–38; 2016b, p. 18).

Vale was considering phasing out smelting and refining at Thompson, owing to Canadian sulfur dioxide emission standards that came into effect in 2015. The company was allowed to continue smelting and refining through 2018, subject to negotiation of emission limits with Environment Canada (Vale S.A., 2016a, p. 37).

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. This was the same as its Canadian production in 2014 (Glencore plc, 2016, p. 189).

The Fort Saskatchewan refinery, a joint venture of Sherritt and General Nickel Co. S.A., produced 3,733 t of cobalt as metal powder and briquettes in 2015, 16% more than the 3,210 t produced in 2014). 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., 2016a, p. 10, 56, 87).

China.—China was the world's leading producer and consumer of refined cobalt. In 2015, China's imports of raw materials, production, consumption, and recovery from scrap increased from those of 2014. China's total production, including an estimate for Umicore's Ganzhou Yi Hao plant, was estimated to constitute more than one-half of world refined cobalt production. Nearly 80% of China's cobalt consumption was used to make cathode materials for rechargeable batteries, primarily lithium-ion batteries with cobalt or nickel-cobalt-manganese cathodes (Darton Commodities Ltd., 2016, p. 3; Aidong Xu, 2016, p. 3, 6–10).

Numerous companies refined and (or) processed cobalt in China. As a result of consolidation in recent years, in 2015, more than 90% of China's refined cobalt was produced by 10 companies and nearly 60% was produced by three companies—Jinchuan, Shenzhen GEM High-Tech Co. Ltd. (including subsidiary Jiangsu Cobalt Nickel Metal Co. Ltd.), and Zhejiang Huayou Cobalt Co. Ltd. In 2015, Huayou began production at its newly constructed cobalt refinery in Quzhou, Zhejiang Province, reportedly bringing the company's total refining capacity to 15,000 t/yr of contained cobalt. As a result, Huayou increased its direct involvement in acquiring raw materials from Congo (Kinshasa) and planned to triple its capacity to produce battery precursor materials. The trend of extending their businesses upstream towards raw materials supply and downstream towards cobalt products was being adopted by most of China's cobalt refiners (Darton Commodities Ltd., 2016, p. 8; Aidong Xu, 2016, p. 5).

Only a small portion of China's cobalt production originated from domestic mines. Most of the production was from imported cobalt concentrate and intermediate chemical compounds, the majority of which was sourced from Congo (Kinshasa). China also imported cobalt raw materials from nickel operations in Australia and elsewhere and has been recovering increasing amounts of cobalt from scrap in recent years. A comparison of China's cobalt supply (mine production, imports of raw materials and refined metal, and cobalt recovered

from scrap) with its domestic cobalt consumption and exports indicated a stock buildup of 4,000 to 7,800 t in 2015. At yearend 2015, China reportedly held about 17,000 t of cobalt in stocks (Darton Commodities Ltd., 2016, p. 8, 25; Aidong Xu, 2016, p. 3, 7, 17, 19).

China's State Reserve Bureau (SRB) continued to add cobalt to its national stockpile in 2015. The SRB purchased 400 t of cobalt in September and 1,800 t in November. The cobalt reportedly was sourced mainly from domestic producers Jinchuan and Jiangsu Cobalt Nickel Metal (Darton Commodities Ltd., 2016, p. 10; Aidong Xu, 2016, p. 16).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt and was estimated to represent one-half of global production. Some of the country's cobalt mine production was from copper-cobalt ores mined by industrial or mechanized methods, and some was gathered by tens of thousands of artisanal miners by handpicking cobalt-rich ores. Spencer (2016b) identified a correlation between cobalt prices and the amount of cobalt mine production by artisanal methods and estimated that artisanal mines in Congo (Kinshasa) produced approximately 10,500 t of cobalt in 2015. Some of Congo (Kinshasa)'s ores and concentrates were exported, some were processed in Congo (Kinshasa) to intermediate materials (crude cobalt carbonate, crude cobalt hydroxide, or cobalt-bearing alloys, such as *alliage blanc*), and some were refined in Congo (Kinshasa) to cobalt metal. China was the leading destination for Congo (Kinshasa)'s cobalt exports. In December, the Government of Congo (Kinshasa) extended a moratorium on its 2013 ban on exports of copper and cobalt concentrates until December 31, 2016. The justification for the moratorium was the inadequate power supply to process the concentrates in the country (Ross, 2016).

In 2015, the Government of Congo (Kinshasa) began the process of dividing its existing 11 Provinces into 26. Following the division, the copper-cobalt deposits of the African Copperbelt in the former Katanga Province were located in two Provinces. One was Lualaba Province, with Kolwezi as its capital, in the southwestern part of the former Katanga Province and the other was Haut-Katanga Province, with Lubumbashi as its capital, in the southeastern part of the former Katanga Province (Grossman and Lewis, 2015).

State-owned La Générale des Carrières et des Mines SARL (Gécamines) held a minority interest in most of the copper-cobalt operations in Congo (Kinshasa). In 2015, Gécamines produced an estimated 400 t of refined cobalt at its Shituru refinery in Likasi, down from an estimated 500 t in 2014. In July, Gécamines sold the mining permit for Compagnie Minière du Sud Katanga's Luiswishi and Lukuni copper-cobalt deposits to Congo Dongfang International Mining SPRL (CDM). CDM, a subsidiary of Zhejiang Huayou Cobalt Co., Ltd., was responsible for procuring cobalt concentrates for Huayou's refineries in China and also producing crude cobalt hydroxide at its hydrometallurgical plant in Lubumbashi (La Générale des Carrières et des Mines SARL, 2015; Cobalt Development Institute, 2016a; Darton Commodities Ltd., 2016, p. 8).

Kamoto Copper Company SA (KCC) (Katanga Mining Ltd., Gécamines, and La Société Immobilière du Congo) produced 2,901 t of cobalt cathode in 2015, 4% more than the 2,784 t

produced in 2014. Production would have been significantly higher had the company not ceased processing copper and cobalt in September. Production of concentrates at the Kamoto concentrator and cobalt metal at the Luilu refinery were suspended for up to 18 months, while the company's whole ore leach project was being constructed. Ore extraction from the Kamoto underground mine and its extensions was also suspended, and mining from the KOV and Mashamba East open pits focused on waste mining with production of sufficient incidental ore for processing after the end of the suspension. 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., 2016, p. 1–2, 4, 6, 26).

Boss Mining SPRL [70% Eurasian Resources Group B.V. (ERG) and 30% Gécamines] mined copper-cobalt ore from open pits at Mukondo Mountain and Kabolela and produced oxide and sulfide concentrates at the Kakanda concentrator. Boss Mining's oxide concentrates were exported, primarily to China, and its sulfide concentrates were sent to the Chambishi Metals refinery in Zambia. Darton Commodities Ltd. estimated a decrease in Boss Mining's cobalt production from 8,500 t in 2014 to 3,500 t in 2015. The decreases in cobalt contained in oxide and sulfide concentrates were attributed to changes in ore mineralogy (Darton Commodities Ltd., 2016, p. 15–17).

In 2015, Tenke Fungurume Mining S.A.R.L. [Freeport-McMoRan Inc. (FCX), Lundin, and Gécamines] extracted copper-cobalt ore from an open pit mine, which it processed onsite to produce 16,014 t of cobalt in hydroxide, 20% more than the 13,334 t produced in 2014. The increase in production was attributed to higher cobalt ore grades. In 2015, a higher portion of the hydroxide reportedly was sold to the Freeport Cobalt refinery in Finland, and the remainder was sold under contract or on the spot market. The company forecast that it would sell 15,900 t of cobalt in 2016 (Darton Commodities Ltd., 2016, p. 8; Lundin Mining Corp., 2016a, p. 40; 2016b, p. 25).

Société Congolaise du Traitement du Terril de Lubumbashi (STL) (Groupe Forrest International and Gécamines) processed slag purchased from Gécamines via trading company Groupement du Terril de Lubumbashi (GTL). In 2015, STL (also known as the Big Hill smelter) processed stockpiled slag to produce an estimated 4,200 t of cobalt in *alliage blanc*. The *alliage blanc* was supplied to the Freeport Cobalt Oy refinery in Finland until April 2015, when the offtake agreement expired (Darton Commodities Ltd., 2016, p. 8, 18).

Mutanda Mining SPRL (Glencore and Fleurette Mumi Holding Ltd.) mined copper-cobalt oxide ore from open pits near Kolwezi and produced 16,500 t of cobalt in concentrate and hydroxide, 15% more than the 14,400 t produced in 2014. The increase in production was attributed to ongoing operational improvements. Glencore had an offtake agreement for all of the operation's copper and cobalt production (Fleurette Group, 2016).

Chemaf SPRL mined copper-cobalt ore from the Etoile open pit mine and produced concentrate using heavy media separation technology, which it processed at its solvent extraction–electrowinning (SX–EW) plant at Usoke in Lubumbashi. In 2015, Chemaf reportedly made equipment and process improvements to increase plant throughput, recovery, and capacity (Darton Commodities Ltd., 2016, p. 20).

Ruashi Mining SPRL (75% Jinchuan subsidiary Metorex (Proprietary) Ltd. and 25% Gécamines) produced 4,344 t of cobalt in cobalt hydroxide (3,885 t in 2014) from its Ruashi operation east of Lubumbashi. The 12% increase in production was attributed to an increase in the grade of ore mined and treated. Ruashi comprised a copper-cobalt oxide open pit mine, a mill, and an SX–EW refinery. The cobalt hydroxide was sold to Jinchuan (Jinchuan Group International Resources Co. Ltd., 2016, p. 10, 74).

Société Minière du Katanga SPRL (Somika) mined and beneficiated copper-cobalt ore and refined the concentrate at its hydrometallurgical copper refinery in Lubumbashi. In 2015, the refinery produced 4,554 t of cobalt hydroxide (Province du Katanga Division Provinciale de Mines, 2016).

The La Sino-Congolaise des Mines S.A. (Sicomines) joint venture (China Railway Group Ltd., Gécamines, Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.) completed construction of its copper-cobalt mine and beneficiation plant and began production of copper and copper-cobalt concentrates. China Railway had two additional operating copper-cobalt mines in Congo (Kinshasa)—Luishia and Minière de Kalumbwe Myunga (China Railway Group Ltd., 2016, p. 28; Province du Katanga Division Provinciale de Mines, 2016).

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 sulfides, which were sent to the joint venture's Fort Saskatchewan refinery in Canada. In 2015, the sulfides contained 37,020 t of nickel and cobalt, slightly more than the 36,410 t produced in 2014 (Sherritt International Corp., 2016a, p. 87).

The Ernesto Che Guevara operation (also known as Punta Gorda) in Moa, Holguin Province, mined and processed nickel-cobalt laterites. In 2015, the processing plant reportedly was undergoing a debottlenecking program to increase output from about 30,000 t/yr of nickel plus cobalt to 36,000 t/yr of nickel plus cobalt. Nickel and cobalt originating in Cuba could not be imported into the United States because of a United States embargo on imports from Cuba (Wood Mackenzie Ltd., undated).

Finland.—Freeport Cobalt Oy (FCX, Lundin, and Gécamines) produced 23% less cobalt at its refinery in Kokkola compared with production in 2014. The decrease was attributed to weaker demand from Japanese battery producers and a loss of market share in some end-use markets. The company produced a wide range of cobalt chemicals and metal powders. In 2015, Freeport reportedly increased its use of intermediate cobalt hydroxides from the joint-venture partners' Tenke Fungurume operation in Congo (Kinshasa). The plant's offtake agreement for alliage blanc from GTL's Big Hill smelter in Congo (Kinshasa) ended in April 2015 (Darton Commodities Ltd., 2016, p. 8; Geological Survey of Finland, 2016; Freeport Cobalt Oy, undated).

Norilsk's Harjavalta nickel refinery produced two cobalt products—cobalt sulfate and an intermediate cobalt sulfate solution. The refinery's main sources of feed in 2015 included converter matte from BCL in Botswana and BHP Billiton in Australia; nickel concentrates from Norilsk's Nkomati Mine in South Africa, Mirabela Nickel in Brazil, Canadian Royalties

Inc. in Canada, and Titania AS in Norway; nickel matte from Kola MMC in Russia; and intermediate nickel-cobalt sulfide from Talvivaara Mining Co. Plc's operation in Finland. The nickel concentrates were toll smelted by Boliden AB prior to processing by Norilsk. In 2015, improvements were made to the refinery, with the intent of using more feed from Russia and less from other companies (PJSC MMC Norilsk Nickel, 2015; 2016b, p. 16–17, 67, 73).

First Quantum produced mineral concentrates at its Kevitsa open pit nickel-copper-PGM sulfide mine and beneficiation plant. In 2015, the plant produced nickel concentrate containing 8,805 t of nickel and, based on an estimated nickel-to-cobalt ratio of 21:1 in the ore reserves, an estimated 420 t of cobalt (9,433 t of nickel and an estimated 450 t of cobalt in 2014) (First Quantum Minerals Ltd., 2016, p. 37).

In August, Terrafame Oy (a subsidiary of Terrafame Group Oy, owned by the Government of Finland) acquired the business and assets of Talvivaara Sotkamo Ltd. (a subsidiary of Talvivaara Mining Co. Plc) and restarted the polymetallic sulfide mining and bioheap-leaching operation in Sotkamo, central Finland. By yearend, the company had produced intermediate nickel-cobalt sulfide containing 578 t of nickel and an estimated 20 t of cobalt (Terrafame Oy, 2016, p. 3–4, 12).

Boliden AB changed its business strategy for nickel at its Harjavalta smelter. From mid-2015, Boliden stopped toll smelting nickel concentrates owned by other companies and instead began processing purchased nickel concentrates and selling the resulting nickel matte (Boliden AB, 2016, p. 27).

France.—According to the Cobalt Development Institute (2016a), Eramet s.a.'s production of cobalt chloride from its refinery at Sandouville was 39% less than production in 2014. Feed for the refinery was nickel matte imported from Eramet subsidiary Société Le Nickel's Doniambo smelter in New Caledonia.

India.—According to an estimate by the Cobalt Development Institute (2016a), India's estimated cobalt production increased by 50% from that of 2014. India's leading cobalt producer was Nicomet Industries Ltd. The company's products included cobalt metal and cobalt sulfate (Nicomet Industries Ltd., undated).

Indonesia.—PT Vale Indonesia Tbk produced cobalt-bearing nickel matte from lateritic ores at its integrated mining and smelting operation near Sorowako on Sulawesi Island. Vale Indonesia sold its matte production to Vale Canada Ltd. (80%) and Sumitomo Metal Mining Co., Ltd. (20%) under life-of-mine agreements. Most of the matte was sent to nickel refineries in Japan (Vale S.A., 2016a, p. 39)

Japan.—Sumitomo's production of electrolytic cobalt at its Niihama nickel refinery increased by 17% from that of 2014. The refinery processed intermediate nickel-cobalt sulfides from the Coral Bay Nickel Corp. and Taganito HPAL Nickel Corp. plants in the Philippines and nickel matte from PT Vale in Indonesia and elsewhere. Some of the refinery's intermediate cobalt chloride reportedly was sent to Sumitomo's Isoura battery materials plant, also in Niihama, to produce NCA battery cathode materials (Cobalt Development Institute, 2016a; Darton Commodities Ltd., 2016, p. 11).

Madagascar.—In 2015, the Ambatovy joint venture (Sherritt, Sumitomo Corp., and Korea Resources Corp.) produced 48,995 t of nickel and cobalt in intermediate sulfide (40,267 t in 2014) and 3,464 t of cobalt metal (2,915 t in 2014). The Ambatovy project comprised mining nickel-cobalt laterite ore in east-central Madagascar and transporting slurried ore by pipeline to a processing plant and refinery located near the Port of Toamasina (Sherritt International Corp., 2016b, p. 12, 24).

Morocco.—Cie. de Tifnout Tighanimine (CTT) [a subsidiary of Groupe Managem (Casablanca)] mined cobalt arsenide ores and produced cobalt hydroxide at Bou-Azzer. The hydroxide was refined to cobalt cathode and oxide at CTT's Guemassa hydrometallurgical refinery north of Marrakech. CTT also had the capability to produce cobalt cathode from tailings generated during past mining operations at Bou-Azzer. In 2015, CTT's production of refined cobalt increased by 24%, owing to increases in feed materials and recovery rates (Groupe Managem, 2016, p. 40–41).

New Caledonia.—Vale continued to ramp up production at its Vale New Caledonia project in the southern tip of New Caledonia's main island. The project comprised a nickel-cobalt laterite mine, a high-pressure acid-leaching processing plant, and a refinery. In 2015, Vale produced 2,391 t of cobalt from New Caledonia (1,384 t in 2014). Statistics from the Government of New Caledonia indicated that Vale produced 1,568 t of cobalt in carbonate (435 t in 2014). Following rampup, Vale New Caledonia was expected to have a nominal production capacity of 57,000 t/yr of nickel contained in nickel oxide and 4,500 t/yr of cobalt contained in an intermediate cobalt carbonate (Direction de l'Industrie, des Mines et de l'Energie, 2016; Vale S.A., 2016a, p. 39, 49).

Lateritic nickel-cobalt ore was exported to the Palmer Nickel and Cobalt Refinery in Queensland, Australia, for processing. Nickel matte from Société Le Nickel's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where nickel products and cobalt chloride were produced. In late 2015, Eramet announced that it planned to cease production of matte at Doniambo and increase its output of ferronickel instead (Eramet s.a., 2016, p. 31).

Norway.—Glencore's production of cobalt cathode at its Nikkelverk refinery was 14% less than that of 2014. The company's Sudbury and Raglan operations in Canada supplied 26% of the cobalt refined at Nikkelverk; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies. The decrease in production was the result of a decrease in cobalt recovered from feed materials sourced from other companies (Darton Commodities Ltd., 2016, p. 9; Glencore plc, 2016, p. 189).

Papua New Guinea.—The Ramu Nickel joint venture (operated by majority owner Metallurgical Corporation of China Ltd.) continued to ramp up production from its Kurumbukari nickel-cobalt laterite mine and Basamuk high-pressure acid-leaching processing plant. In 2015, the operation produced 2,505 t of cobalt in intermediate nickel-cobalt hydroxide (2,134 t in 2014). The hydroxide was exported to China for refining (Highlands Pacific Ltd., 2016, p. 8–9).

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) produced intermediate nickel-cobalt sulfide from its high-pressure acid-leaching operation at the Rio Tuba nickel laterite mine on Palawan Island. Taganito HPAL Nickel Corp. (Sumitomo, Nickel Asia Corp., and Mitsui, listed in order of share) produced intermediate nickel-cobalt sulfide from its high-pressure acid-leaching processing plant at Nickel Asia's Taganito laterite mine in the northeastern region of Mindanao Island. Sulfides from Coral Bay and Taganito were sent to Sumitomo's Niihama refinery in Japan.

Russia.—According to the Cobalt Development Institute (2016a), Norilsk produced 2,040 t of refined cobalt, 11% less than the 2,302 t produced in 2014. Norilsk mined and beneficiated nickel-copper sulfide ores, smelted the concentrates, and refined the matte on the Taimyr Peninsula and the Kola Peninsula. On the Taimyr Peninsula, Norilsk's Polar Division's Nickel Plant produced cobalt ingot and cobalt oxide from local ores. The company planned to close the Polar Division's nickel smelter and refinery and cease the Division's cobalt production in 2016 (PJSC MMC Norilsk Nickel, 2016b, p. 14–15, 73, 82).

At Norilsk's Severonikel refinery at Monchegorsk on the Kola Peninsula, Kola MMC processed cobalt-bearing nickel materials originating from Kola, the Polar Division, and elsewhere to make an intermediate cobalt hydroxide. The hydroxide reportedly was sent to China and elsewhere for refining. Kola MMC completed construction of a cobalt refinery at Monchegorsk and, in December, began producing high-grade cobalt cathode (Darton Commodities Ltd., 2016, p. 18; PJSC MMC Norilsk Nickel, 2016a, p. 36; 2016b, p. 16–17, 86).

South Africa.—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Norilsk) produced 1,112 t of cobalt in nickel concentrate in 2015 (1,096 t in 2014). Concentrate from Nkomati was refined at Norilsk's Harjavalta refinery. In late 2014, Norilsk announced that it had entered an agreement to sell its share in Nkomati to BCL in Botswana; the sale had not closed by yearend 2015. As part of the sale agreement, BCL was to take over Norilsk's offtake agreement for Nkomati concentrate and Norilsk was to buy nickel matte from BCL to refine at Harjavalta (Antonioli, 2014; African Rainbow Minerals Ltd., 2015, p. 83; 2016, p. 17; PJSC MMC Norilsk Nickel, 2016b, p. 17, 69, 236).

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. Impala Platinum Ltd. produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province. Some of the cobalt produced by Impala was recovered from concentrates produced at the Mimosa platinum mine in Zimbabwe. Two other platinum producers—Lonmin plc and Northam Platinum Ltd.—operated base-metals refineries and produced intermediate nickel sulfate containing cobalt.

Spain.—Lundin mined nickel-copper sulfide ore containing cobalt and precious metals from its Aguablanca operation in Badajoz Province and produced nickel-copper concentrate containing 16% less nickel than that of 2014. The decrease was

attributed to shifting from open pit to underground mining early in the year, and then suspending underground mining during the third quarter. In early 2016, Lundin announced that it planned to permanently close the mine, owing to low nickel and copper prices (Lundin Mining Corp., 2016b, p. 23).

Turkey.—Meta Nikel Kobalt A.Ş. (Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) commissioned a high-pressure acid-leach plant at Gordes and began trial production in December 2014. In 2015, commercial production of intermediate nickel-cobalt hydroxide began. The plant used nickel laterite ore from mines in Gordes in Manisa Province and Yunusemre in Eskisehir Province as feed. The mixed hydroxide product was exported to China (Vestel Elektronik Sanayi ve Ticaret AŞ, 2015, p. 47).

Vietnam.—Ban Phuc Nickel Mines LLP (Asian Mineral Resources Ltd.'s subsidiary AMR Nickel Ltd. and state-owned Mineral Development Co.) produced 277 t of cobalt in nickel-copper concentrate (223 t in 2014). The Ban Phuc Mine and beneficiation plant were located about 160 kilometers west of Hanoi in Son La Province (Asian Mineral Resources Ltd., 2016, p. 2, 7).

Zambia.—Cobalt is present in many of Zambia's copper deposits, but Zambian copper operations do not report their cobalt mine output. Production of refined cobalt, which was mainly from imported concentrates, decreased steeply from that of 2014.

According to the Cobalt Development Institute (2016a), Chambishi Metals plc (90% ERG and 10% ZCCM Investments Holdings Plc) produced 2,997 t of cobalt metal at its Chambishi refinery, 31% less than the 4,317 t produced in 2014. The decrease was the result of production being suspended from April into July, owing to a shortage of feed. The main source of feed for the refinery had been copper-cobalt sulfide concentrate from Boss Mining's operations in Congo (Kinshasa). As cobalt levels in the sulfide ores declined, Chambishi began diversifying its feed, including importing cobalt hydroxide from Tenke Fungurume (Metal Bulletin Daily, 2015a; Darton Commodities Ltd., 2016, p. 12).

Konkola Copper Mines Plc (KCM) (Vedanta Resources Ltd. and ZCCM Investments Holdings) mined copper ores from its Nchanga and Konkola operations. Cobalt in concentrate, mainly from the Nchanga open pit, was processed to a copper-iron-cobalt alloy at the company's Nchanga copper smelter in Chingola. In addition to feed from KCM's mines, the smelter also processed copper-cobalt concentrates from other companies. Darton Commodities Ltd. (2016, p. 19) estimated that KCM's production of cobalt in alloy decreased from 1,700 t in 2014 to 1,400 t in 2015, owing to lower feed grades, lower equipment availability, and power restrictions at Nchanga.

China Nonferrous Mining Corp. Ltd. (CNMC) mined and processed copper-cobalt ore in the Zambian Copperbelt through four majority-owned subsidiaries—NFC Africa Mining Plc. (NFCA), CNMC Luanshya Copper Mines Plc. (CLM), Chambishi Copper Smelter Ltd. (CCS), and Sino-Metal Leach Zambia Ltd. CCS smelted copper concentrates from NFCA, CLM, and other miners. In September, production was suspended at CLM's Baluba Center Mine, processing plant, and slag copper recovery project owing to a 30% reduction in

electricity supply. In 2015, CCS began trial production from its converter slag reduction furnace project, which had the capacity to process 100,000 t/yr of slag. The project was designed to produce 10,350 t/yr of copper-cobalt alloy containing 9.27% cobalt (approximately 960 t/yr of cobalt in alloy). The second phase of the project, known as the High Grade Cobalt Matte Metallurgy project, was to process 50,000 t/yr of matte beginning in 2016 (table 7) (China Nonferrous Mining Corp. Ltd., 2016, p. 9, 20, 30–31, 37).

Consolidated Nickel Mines plc (CNM) had a lease and royalty agreement with Jinchuan for full operational control of the Munali nickel mine and concentrator in southern Zambia. CNM planned to restart operations at Munali in 2016, following receipt of the necessary agreements and permissions from the Government of Zambia. The mine was expected to produce nickel concentrate containing 160 t/yr of cobalt, which would be smelted in southern Africa (Consolidated Nickel Mines plc, 2015, undated a, b).

Glencore's Sable Zinc Kabwe Ltd. copper electrowinning plant did not operate during 2015. In 2014, the Sable plant processed feed from third-party sources and produced 500 t of cobalt in hydroxide. Mopani Copper Mines Plc (Glencore, First Quantum, and ZCCM Investment Holdings, listed in order of share) kept its Nkana cobalt refinery on care-and-maintenance status in 2015 (Glencore plc, 2016, p. 185).

Zimbabwe.—The Mimosa platinum mine (Aquarius Platinum Ltd. and Impala Platinum Holdings Ltd.) produced 88 t of cobalt in concentrate (90 t in 2014). The concentrates were refined by Impala in South Africa (Aquarius Platinum Ltd., 2015, p. 10; 2016, p. 13).

Zimplats Holdings Ltd. produced 56 t of cobalt from its platinum operations in 2015 (58 t in 2014). The company completed feasibility studies on refurbishing the mothballed base-metals refinery at its Selous Metallurgical Complex in Mashonaland West Province and began work on the project. The cobalt-bearing nickel sulfate produced from the base-metals refinery would be further refined at other refineries in Zimbabwe (Zimplats Holdings Ltd., 2015, p. 17, 21; 2016, p. 4).

Bindura Nickel Corp. (BNC) operated the Trojan nickel sulfide mine and shipped concentrate to offtake partner Glencore. During the year, BNC worked to refurbish its nickel smelter and planned to produce a nickel leach alloy from concentrates produced at Trojan and other mines in Zimbabwe. The company's Shangani Mine and refinery remained on care-and-maintenance status (Asa Resource Group plc, 2015, p. 2, 8, 22, 26).

Outlook

Trends in cobalt consumption closely follow those of global industrial production. Increasing consumption, particularly for rechargeable batteries for vehicles and other applications, superalloys, and cemented carbide and diamond tools, is forecast to result in a 68% increase in total cobalt consumption from 2015 to 2025 (Spencer, 2016a, p. 6).

Global cobalt supply was forecast to decrease in 2016 compared with that of 2015. With regard to concentrates and partially refined materials, the combined decrease in production from some operations was forecast to be greater than the

combined increase from others. With regard to refined cobalt supply, during the first half of 2016, world production of refined cobalt was estimated to have been 5% less than that of the first half of 2015. Production from China, the leading source of refined cobalt, decreased by a significant amount and operations at three refineries—Kamoto Copper Company’s refinery in Congo (Kinshasa), the Palmer Nickel and Cobalt Refinery in Australia, and Votorantim’s refinery in Brazil—were suspended for economic and (or) other reasons beginning in late 2015 or early 2016 (Cobalt Development Institute, 2016b; Darton Commodities Ltd., 2016, p. 26; Spencer, 2016a, p. 9; Shedd, 2017).

Global cobalt supply was expected to increase from 2017 onward. However, the growth in supply was forecast to increase at a lower rate than that of world cobalt consumption. Cobalt stockpiles in China are reportedly being drawn down. A shift from surplus to deficit was forecast for 2016. Without new producers entering the market in the medium term, or a major shift to battery chemistries with less cobalt, an extended period of undersupply could take place (Cobalt Development Institute, 2016b; Darton Commodities Ltd., 2016, p. 37–38; Spencer, 2016a, p. 9, 14, 16, 20).

References Cited

- African Rainbow Minerals Ltd., 2015, Integrated annual report 2015: Sandton, South Africa, African Rainbow Minerals Ltd., 312 p.
- African Rainbow Minerals Ltd., 2016, Interim results for the six months ended 31 December 2015: Sandton, South Africa, African Rainbow Minerals Ltd., 48 p.
- Antonoli, Silvia, 2014, Norilsk to sell African nickel stakes to Botswana’s BCL for \$337 mln: Gaborone, Botswana, Thomson Reuters, October 20. (Accessed October 11, 2016, at <http://www.reuters.com/article/norilskafrika-ma-bcl-idUSL3N0SF54920141020>.)
- Aquarius Platinum Ltd., 2015, Fourth quarter 2015—Production results—Production results to 30 June 2015: Hamilton, Bermuda, Aquarius Platinum Ltd., 12 p.
- Aquarius Platinum Ltd., 2016, Second quarter 2016—Production results—Production results to 31 December 2015: Hamilton, Bermuda, Aquarius Platinum Ltd., 15 p.
- Asa Resource Group plc, 2015, Interim unaudited results: London, United Kingdom, Asa Resource Group plc half yearly report 2015, December 11, 27 p.
- Asian Mineral Resources Ltd., 2016, Management’s discussion and analysis—Year ended December 31, 2015: Toronto, Ontario, Canada, Asian Mineral Resources Ltd., April 29, 29 p.
- BHP Billiton Plc, 2016, Annual report 2016: London, United Kingdom, BHP Billiton Plc, 292 p.
- Boliden AB, 2016, Annual report 2015: Stockholm, Sweden, Boliden AB, 120 p.
- China Nonferrous Mining Corp. Ltd., 2016, 2015 annual report: Beijing, China, China Nonferrous Mining Corp. Ltd., 172 p.
- China Railway Group Ltd., 2016, Annual report 2015: Beijing, China, China Railway Group Ltd., 224 p.
- Cobalt Development Institute, 2016a, 2015 production statistics: Cobalt News, no. 2, April, p. 3–5.
- Cobalt Development Institute, 2016b, 2016 first half production statistics: Cobalt News, no. 4, October, p. 3–4.
- Consolidated Nickel Mines plc, 2015, Re-starting the Munali nickel mine—Offering near term brownfields production in Zambia—February 2015: London, United Kingdom, Consolidated Nickel Mines plc fact sheet, February. (Accessed February 25, 2016, at <http://www.cnmplc.co.uk/wp-content/uploads/2015/03/CLICK-HERE-FOR-THE-MUNALI-MINE-FACT-SHEET.pdf>.)
- Consolidated Nickel Mines plc, [undated]a, The Munali nickel mine: London, United Kingdom, Consolidated Nickel Mines plc. (Accessed February 25, 2016, at <http://www.cnmplc.co.uk/the-munali-nickel-mine/>.)
- Consolidated Nickel Mines plc, [undated]b, Who we are & what we do: London, United Kingdom, Consolidated Nickel Mines plc. (Accessed February 25, 2016, at <http://www.cnmplc.co.uk/who-we-are-what-we-do/>.)
- Darton Commodities Ltd., 2016, Cobalt market review 2015–2016: Guildford, United Kingdom, Darton Commodities Ltd., January, 41 p.
- Defense Logistics Agency Strategic Materials, 2015, Annual materials plan for FY 2016 for possible acquisition of new NDS stocks: Fort Belvoir, VA, Defense Logistics Agency Strategic Materials news release, October 1, 1 p.
- Department of Natural Resources and Mines, 2016, Queensland’s metalliferous and industrial minerals—2015: Brisbane, Queensland, Australia, Department of Natural Resources and Mines, Geological Survey of Queensland, 83 p. (Accessed July 7, 2016, at https://www.dnrm.qld.gov.au/_data/assets/pdf_file/0009/374859/metalliferous-industrial-minerals.pdf.)
- Direction de l’Industrie, des Mines et de l’Energie, 2016, Productions et exportations minières & métallurgiques de la Nouvelle-Calédonie—Décembre 2015: Noumea, New Caledonia, Direction de l’Industrie, des Mines et de l’Energie. (Accessed February 19, 2016, at https://dimenc.gouv.nc/sites/default/files/statistiques_nc_2015_-_12.pdf.)
- Eramet s.a., 2016, Annual report 2015: Paris, France, Eramet s.a., 57 p.
- First Quantum Minerals Ltd., 2016, Management’s discussion and analysis for the year ended December 31, 2015: Vancouver, British Columbia, Canada, First Quantum Minerals Ltd., February 18, 48 p.
- Fleurette Group, 2016, Mutanda Mining SARL—Fourth quarter and 2015 calendar year production report: Kinshasa, Congo (Kinshasa), Fleurette Group news release, February 11, 2 p.
- Formation Metals Inc., 2016, Corporate presentation: Vancouver, British Columbia, Canada, Formation Metals Inc., March, 47 p. (Accessed March 21, 2016, at <http://www.formationmetals.com/i/pdf/CompanyPowerpointPresentation.pdf>.)
- Freeport Cobalt Oy, [undated], Recycling: Kokkola, Finland, Freeport Cobalt Oy. (Accessed February 2, 2015, at <http://www.freeportcobalt.com/products/chemical.html#recycling>.)
- Geological Survey of Finland, 2016, Metals and minerals production 2011–2015: Espoo, Finland, Geological Survey of Finland, May 5. (Accessed August 5, 2016, at <http://en.gtk.fi/information/services/mineralproduction/finmipr1115.html>.)
- Glencore plc, 2016, Annual report 2015: Baar, Switzerland, Glencore plc, 202 p.
- Global Tungsten & Powders Corp., 2014, Global Tungsten & Powders announces strategic cobalt partnership with Umicore: Towanda, PA, Global Tungsten & Powders Corp. news release, August 25, 1 p.
- Grossman, Guy, and Lewis, J.I., 2015, The Democratic Republic of Congo might break up its Provinces. Then what?: The Washington Post, June 4. (Accessed February 25, 2016, at <https://www.washingtonpost.com/blogs/monkey-cage/wp/2015/06/04/the-democratic-republic-of-congo-might-break-up-its-provinces-then-what/>.)
- Groupe Managem, 2016, Rapport annuel 2015: Casablanca, Morocco, Groupe Managem, 128 p.
- Highlands Pacific Ltd., 2016, 2015 annual report: Brisbane, Queensland, Australia, Highlands Pacific Ltd., 67 p.
- Jinchuan Group International Resources Co. Ltd., 2016, Annual report 2015: Hong Kong, China, Jinchuan Group International Resources Co. Ltd., 180 p.
- Katanga Mining Ltd., 2016, Management’s discussion and analysis for the three months and years ended December 31, 2015 and 2014: Whitehorse, Yukon Territory, Canada, Katanga Mining Ltd., 37 p.
- La Générale des Carrières et des Mines SARL, 2015, Communiqué sur la cession du permis d’exploitation 527: Lubumbashi, Congo (Kinshasa), La Générale des Carrières et des Mines SARL news release, July 4, 2 p.
- London Metal Exchange Ltd., The, [undated]a, List of all LME-approved brands by metal: London, United Kingdom, The London Metal Exchange Ltd. (Accessed January 28, 2016, via <https://www.lme.com/trading/warehousing-and-brands/brands/approved-brands/>.)
- London Metal Exchange Ltd., The, [undated]b, Physical contract specification: London, United Kingdom, The London Metal Exchange Ltd. (Accessed February 26, 2016, at <http://www.lme.com/metals/minor-metals/cobalt/contract-specifications/physical/>.)
- Lundin Mining Corp., 2016a, Annual information form for the year ended December 31, 2015: Toronto, Ontario, Canada, Lundin Mining Corp., March 30, 69 p.
- Lundin Mining Corp., 2016b, Management’s discussion and analysis for the year ended December 31, 2015: Toronto, Ontario, Canada, Lundin Mining Corp., February 18, 51 p.
- Metal Bulletin Daily, 2015a, ENRC will restart cobalt production at Chambishi this month: Metal Bulletin Daily, no. 9414.1, July 6, p. 9.
- Metal Bulletin Daily, 2015b, First Quantum expects production restart at Ravensthorpe nickel mine by July 31: Metal Bulletin Daily, no. 9416.4, July 23, p. 5–6.

- Metal Bulletin Daily, 2016, Votorantim will stop nickel, cobalt production in Brazil: Metal Bulletin Daily, no. 9441.3, January 20, p. 1.
- Mincor Resources NL, 2015, Quarterly report for the period ended 30 June 2015: West Perth, Western Australia, Australia, Mincor Resources NL, 16 p.
- Mincor Resources NL, 2016, Quarterly report for the period ended 31 December 2015: West Perth, Western Australia, Australia, Mincor Resources NL, 5 p.
- Mirabela Nickel Ltd., 2015, Quarterly activity report for the period ended 30 June 2015: Perth, Western Australia, Australia, Mirabela Nickel Ltd., July 30, 5 p.
- Mirabela Nickel Ltd., 2016, Operational update: Perth, Western Australia, Australia, Mirabela Nickel Ltd. news release, February 19, 1 p.
- Nicomet Industries Ltd., [undated], About us—Profile: Mumbai, India, Nicomet Industries Ltd. (Accessed March 21, 2016, at <http://www.nicomet.com/aboutus.htm>.)
- n.v. Umicore, s.a., 2015a, Annual report 2014: Brussels, Belgium, n.v. Umicore, s.a., 196 p.
- n.v. Umicore, s.a., 2015b, Umicore set to invest in cobalt refining and recycling plant in Olen, Belgium: Brussels, Belgium, n.v. Umicore, s.a. news release, September 30, 1 p.
- n.v. Umicore, s.a., [undated], Plants and offices: Brussels, Belgium, n.v. Umicore, s.a. (Accessed December 29, 2016, at <http://csm.umicore.com/en/about-us/>.)
- Panoramic Resources Ltd., 2015, Quarterly report for the period ending 30 June 2015: Perth, Western Australia, Australia, Panoramic Resources Ltd., July 29, 27 p.
- Panoramic Resources Ltd., 2016, Quarterly report for the period ending 31 December 2015: Perth, Western Australia, Australia, Panoramic Resources Ltd., January 29, 20 p.
- PJSC MMC Norilsk Nickel, 2015, Grand commissioning of new processing facilities at Norilsk Nickel Harjavalta: Moscow, Russia, PJSC MMC Norilsk Nickel press release, November 10. (Accessed February 16, 2016, at <http://www.nornik.ru/en/newsroom/news-and-press-releases/news/grand-commissioning-of-new-processing-facilities-at-norilsk-nickel-harjavalta>.)
- PJSC MMC Norilsk Nickel, 2016a, 2015 financial results: Moscow, Russia, PJSC MMC Norilsk Nickel, presentation, March 15, 42 p.
- PJSC MMC Norilsk Nickel, 2016b, Annual report 2015: Moscow, Russia, PJSC MMC Norilsk Nickel, 240 p.
- PolyMet Mining Corp., 2016, Form 20–F for the fiscal year ended January 31, 2016: U.S. Securities and Exchange Commission, 62 p.
- Province du Katanga Division Provinciale de Mines, 2016, Statistiques des notes de débit relatives à la redevance minière émises de janvier à décembre 2015: Lubumbashi, Congo (Kinshasa), Province du Katanga Division Provinciale de Mines, January 5. (Accessed April 12, 2016, at http://www.congomines.org/system/attachments/assets/000/001/085/original/Statistiques_2015.pdf?1454424782.)
- Ross, Aaron, 2016, Congo delays ban on copper and cobalt concentrate exports: Thomson Reuters, January 13. (Accessed January 13, 2016, at <http://af.reuters.com/article/investingNews/idAFKCN0UR0IV20160113>.)
- Shedd, K.B., 2017, Cobalt: U.S. Geological Survey Mineral Commodity Summaries 2017, p. 52–53.
- Sherritt International Corp., 2016a, 2015 annual information form: Toronto, Ontario, Canada, Sherritt International Corp., 101 p.
- Sherritt International Corp., 2016b, 2015 annual report: Toronto, Ontario, Canada, Sherritt International Corp., 144 p.
- Spencer, Edward, 2016a, Cobalt supply and demand—A global perspective: The Cobalt Conference, Cobalt Development Institute, Seoul, Republic of Korea, May 11–12, presentation, 22 p.
- Spencer, Edward, 2016b, The true extent of the DRC’s artisanal cobalt industry: London, United Kingdom, CRU Group, March 22. (Accessed March 22, 2016, at <http://www.crugroup.com/about-cru/cruinsight/DRC-Artisanal-Cobalt-Industry>.)
- Stillwater Mining Co., 2016, 2015 annual report: Littleton, CO, Stillwater Mining Co., 112 p.
- Terrafame Oy, 2016, Annual report 2015: Tuhkakyla, Finland, Terrafame Oy, 129 p.
- U.S. Department of Defense, 2016, Strategic and critical materials operations report to Congress—Operations under the Strategic and Critical Materials Stock Piling Act during fiscal year 2015: Fort Belvoir, VA, U.S. Department of Defense, January, 72 p.
- Vale S.A., 2015, Form 20–F for the fiscal year ended December 31, 2014: U.S. Securities and Exchange Commission, 164 p.
- Vale S.A., 2016a, Form 20–F for the fiscal year ended December 31, 2015: U.S. Securities and Exchange Commission, 174 p.
- Vale S.A., 2016b, Vale’s production in 4Q15: Rio de Janeiro, Brazil, Vale S.A. press release, February 18, 24 p.
- Vestel Elektronik Sanayi ve Ticaret AŞ, 2015, 2015 annual report: Istanbul, Turkey, Vestel Elektronik Sanayi ve Ticaret AŞ, 168 p.
- Westbrook, Tom, 2016, Nickel shipments diverted as Palmer plant runs out of ore: Thomson Reuters, March 11. (Accessed October 3, 2016, at <http://www.reuters.com/article/queensland-nickel-shutdown-idUSL4N16K03J>.)
- Wood Mackenzie Ltd., [undated], Punta Gorda nickel operation: Edinburgh, United Kingdom, Wood Mackenzie Ltd. (Accessed September 27, 2016, at <https://www.woodmac.com/reports/metals-punta-gorda-nickel-operation-15920389>.)
- Xu, Aidong, 2016, China cobalt industry review: The Cobalt Conference, Cobalt Development Institute, Seoul, Republic of Korea, May 11–12, presentation, 22 p.
- Xu, Anna, 2016, Yunnan tells Fanya investors to make claims before end-June: Metal Bulletin, June 23. (Accessed June 23, 2016, via <http://www.metalbulletin.com>.)
- Zimplats Holdings Ltd., 2015, Integrated annual report 2015: St. Peter Port, Guernsey [United Kingdom], Zimplats Holdings Ltd., 168 p.
- Zimplats Holdings Ltd., 2016, Directors’ report and condensed consolidated interim financial statements—Half year ended 31 December 2015: St. Peter Port, Guernsey [United Kingdom], Zimplats Holdings Ltd., 20 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Cobalt. Ch. in Mineral Commodity Summaries, annual.
- Cobalt. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
- 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.
- Co-Cu-Au Deposits in Metasedimentary Rocks—A Preliminary Report. Open-File Report 2010–1212, 2010.
- Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
- Magmatic Sulfide-Rich Nickel-Copper Deposits Related to Picrite and (or) Tholeiitic Basalt Dike-Sill Complexes—A Preliminary Deposit Model. Open-File Report 2010–1179, 2010.
- Ni-Co Laterite Deposits of the World—Database and Grade and Tonnage Models. Open-File Report 2011–1058, 2011.
- Sediment-Hosted Copper Deposits of the World—Deposit Models and Database. Open-File Report 03–107, 2003.

Other

- Cobalt. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
- Cobalt. Mineral Profile, British Geological Survey, 2009.
- 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)

	2011	2012	2013	2014	2015	
United States:						
Mine production ^e	(2)	(2)	(2)	120	760	
Consumption:						
Reported	9,180	8,660	8,090	8,560	8,780	
Apparent	9,300 ^r	9,540 ^r	8,650 ^r	8,710 ^r	10,300	
Imports for consumption	10,600	11,100	10,400 ^r	11,300 ^r	11,400	
Exports	3,320 ^r	3,760	3,850	4,500	3,830	
Stocks, December 31:						
Industry ³	784	730	821	1,160 ^r	1,080	
London Metal Exchange (LME), U.S. warehouse	43	51	41	9	165	
U.S. Government:⁴						
Metal	301	301	301	301	301	
Lithium-cobalt oxide ^e	--	--	--	0.055	0.145	
Lithium-nickel-cobalt-aluminum oxide ^e	--	--	--	0.007	0.062	
Price, metal:						
U.S. spot ⁵	dollars per pound	17.99	14.07	12.89	14.48	13.44
LME, cash ⁶	do.	16.01	13.06	12.26	14.00	12.90
World:						
Production:						
Mine ^e	111,000	105,000 ^r	114,000	122,000 ^r	126,000	
Refinery	82,400	78,100	86,700 ^r	92,700 ^r	97,400	
Stocks, December 31, LME ⁷	304	429	560	489	630	

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

¹Data are rounded to no more than three significant digits, except prices.

²Negligible.

³Stocks held by cobalt processors and consumers.

⁴Source: Defense Logistics Agency Strategic Materials. The cobalt content of compounds listed was estimated as 60% of gross weight for lithium-cobalt oxide and 9% of gross weight for lithium-nickel-cobalt-aluminum oxide.

⁵Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.

⁶Annual 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.

⁷Stocks held in Asia, Europe, and the United States.

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

(Metric tons, cobalt content)

	2014	2015
Consumption by end use:		
Steels and other alloys, excludes superalloys ³	1,510	1,390
Superalloys	3,930	3,960
Cemented carbides ⁴	783	726
Chemical and ceramic uses	2,330	2,710
Total	8,560	8,780
Consumption by form:		
Chemical compounds, organic and inorganic ⁵	2,190	2,060
Metal	4,170	3,980
Purchased scrap	2,200	2,750
Total	8,560	8,780
Stocks, December 31: ⁶		
Chemical compounds, organic and inorganic ⁵	512 ^r	475
Metal	W	W
Purchased scrap	W	W
Total	1,160 ^r	1,080

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

¹Data 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	2014			2015		
	Gross weight (metric tons)	Cobalt content ² (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content ² (metric tons)	Value (thousands)
Metal ³	9,000 ^r	9,000 ^r	\$269,000 ^r	9,290	9,290	\$267,000
Oxides and hydroxides	2,400 ^r	1,730 ^r	57,200 ^r	1,750	1,260	40,200
Other:						
Acetates	239	57	1,880	138	33	1,130
Carbonates	556	256	9,460	783	360	13,800
Chlorides	15	4	157 ^r	16	4	157
Sulfates	1,020	276	7,960	1,690	458	11,200
Total	13,200 ^r	11,300 ^r	346,000 ^r	13,700	11,400	334,000

^rRevised.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Estimated from gross weight.

³Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY¹

Country of origin	Metal ²			Oxides and hydroxides			Other forms ³			Total		
	Gross weight	Cobalt content ⁴	Value ⁵	Gross weight	Cobalt content ⁴	Value ⁵	Gross weight	Cobalt content ⁴	Value ⁵	Gross weight	Cobalt content ⁴	Value ⁵
	(metric tons)	(metric tons)		(metric tons)	(metric tons)		(metric tons)	(metric tons)		(metric tons)	(metric tons)	
2014:												
Australia	975	975	\$27,400	--	--	--	--	--	--	975	975	\$27,400
Belgium	18	18	724	510 ^r	368 ^r	\$13,000 ^r	137	37	\$725	665 ^r	423 ^r	14,500 ^r
Brazil	80	80	2,300	14	10	144	84	25	1,070 ^r	178	115	3,520
Canada	120	120	5,760	1	1	31	--	--	--	121	120	5,790
China	1,400	1,400	40,300	357 ^r	257 ^r	8,150 ^r	280	103	3,590	2,030 ^r	1,760	52,100 ^r
Congo (Kinshasa)	20	20	568	166	120	4,210	--	--	--	186	140	4,780
Finland	617	617	21,600	294	212	7,210	847	285	9,450	1,760	1,110	38,300
France	30 ^r	30 ^r	1,420 ^r	1	1	23	--	--	--	30 ^r	30 ^r	1,454 ^r
Germany	30	30	1,430	5	4	522	5	1	40	40	35	1,990
India	--	--	--	--	--	--	159	43	1,410	159	43	1,410
Japan	1,100 ^r	1,100 ^r	31,700 ^r	(6)	(6)	4	--	--	--	1,100 ^r	1,100 ^r	31,700 ^r
Madagascar	589	589	17,600	--	--	--	--	--	--	589	589	17,600
Mexico	--	--	--	--	--	--	23	11	135	23	11	135
Morocco	117	117	3,560	--	--	--	--	--	--	117	117	3,560
Norway	1,910	1,910	56,800	--	--	--	--	--	--	1,910	1,910	56,800
Russia	930	930	27,200	--	--	--	(6)	(6)	5 ^r	930	930	27,200
South Africa	389	389	11,500	--	--	--	--	--	--	389	389	11,500
Sweden	19	19	937	--	--	--	--	--	--	19	19	937
Taiwan	(6)	(6)	18	--	--	--	131 ^r	35	936 ^r	131 ^r	36	954 ^r
United Kingdom	23	23	1,010	1,040	749	23,700	144	46	1,870	1,210	818	26,600
Zambia	634	634	17,300	--	--	--	--	--	--	634	634	17,300
Other	6	6	281 ^r	10	7	195	22	7	212	39	20	688
Total	9,000 ^r	9,000 ^r	269,000 ^r	2,400 ^r	1,730 ^r	57,200 ^r	1,830	593	19,500	13,200 ^r	11,300 ^r	346,000 ^r
2015:												
Australia	600	600	16,100	--	--	--	--	--	--	600	600	16,100
Belgium	22	22	799	563	406	13,300	94	25	727	679	453	14,800
Brazil	211	211	5,780	--	--	--	63	19	802	274	230	6,580
Canada	384	384	14,000	(6)	(6)	3	3	1	17	388	385	14,000
China	1,470	1,470	43,800	315	227	7,100	732	242	7,890	2,520	1,940	58,800
Finland	528	528	17,100	317	228	7,210	1,110	379	12,100	1,950	1,130	36,400
France	26	26	1,210	--	--	--	--	--	--	26	26	1,210
Germany	81	81	5,060	(6)	(6)	19	4	1	32	86	83	5,120
India	(6)	(6)	7	--	--	--	135	36	886	135	37	894
Italy	8	8	293	(6)	(6)	8	17	5	113	25	13	414
Japan	1,190	1,190	32,800	(6)	(6)	4	1	(6)	17	1,190	1,190	32,900
Korea, Republic of	2	2	81	20	14	272	--	--	--	21	16	353
Madagascar	840	840	24,300	--	--	--	--	--	--	840	840	24,300
Morocco	472	472	12,900	--	--	--	--	--	--	472	472	12,900
Norway	1,730	1,730	48,900	--	--	--	--	--	--	1,730	1,730	48,900
Peru	--	--	--	--	--	--	237	66	596	237	66	596
Russia	830	830	23,700	--	--	--	18	5	106	848	835	23,800
South Africa	501	501	8,870	--	--	--	--	--	--	501	501	8,870
Sweden	15	15	854	--	--	--	--	--	--	15	15	854
Uganda	26	26	674	--	--	--	--	--	--	26	26	674
United Kingdom	37	37	1,430	535	385	12,200	203	71	2,810	775	493	16,500
Zambia	308	308	7,940	--	--	--	--	--	--	308	308	7,940
Other	16	16	480	--	--	--	19	5	190	35	21	671
Total	9,290	9,290	267,000	1,750	1,260	40,200	2,630	855	26,300	13,700	11,400	334,000

^rRevised. -- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Unwrought cobalt, excluding alloys and waste and scrap; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy.

³Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.

⁴Estimated from gross weight.

⁵Customs value.

⁶Less than ½ unit.

Source: U.S. Census Bureau.

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

Country of destination	Metal ³		Oxides and hydroxides		Acetates		Chlorides		Total	
	Gross weight (metric tons)	Value ⁴ (thousands)	Gross weight (metric tons)	Value ⁴ (thousands)	Gross weight (metric tons)	Value ⁴ (thousands)	Gross weight (metric tons)	Value ⁴ (thousands)	Cobalt content ⁵ (metric tons)	Value ⁴ (thousands)
2014	4,070	\$102,000	536	\$5,720	181	\$3,380	3	\$44	4,500	\$111,000
2015:										
Argentina	7	290	--	--	--	--	--	--	7	290
Australia	25	819	(6)	15	--	--	--	--	26	834
Austria	12	279	--	--	--	--	--	--	12	279
Belgium	278	5,380	57	938	141	1,050	--	--	353	7,370
Brazil	3	134	14	346	--	--	--	--	13	480
Canada	846	8,230	(6)	8	--	--	--	--	846	8,240
China	57	1,970	8	322	--	--	--	--	63	2,290
Finland	11	601	--	--	--	--	--	--	11	601
France	788	15,000	--	--	--	--	--	--	788	15,000
Germany	201	10,900	1	29	--	--	--	--	201	10,900
Hong Kong	9	374	98	600	--	--	--	--	79	974
Hungary	7	467	--	--	--	--	--	--	7	467
India	52	2,130	--	--	38	334	--	--	62	2,470
Ireland	639	15,200	--	--	--	--	--	--	639	15,200
Italy	13	885	(6)	16	--	--	--	--	13	901
Japan	187	7,070	--	--	--	--	--	--	187	7,070
Korea, Republic of	65	3,060	--	--	--	--	--	--	65	3,060
Mexico	9	439	10	265	1	10	(6)	4	17	718
Netherlands	66	1,660	1	34	--	--	--	--	66	1,700
Singapore	34	2,100	1	57	--	--	--	--	34	2,160
Taiwan	45	1,190	1	26	--	--	--	--	45	1,220
Turkey	21	620	--	--	--	--	--	--	21	620
United Kingdom	228	5,830	(6)	7	--	--	--	--	228	5,840
Other	42	2,470	1	23	--	--	(6)	3	43	2,490
Total	3,640	87,000	192	2,690	180	1,390	(6)	7	3,830	91,100

-- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

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

³Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.

⁴Free alongside ship value.

⁵Estimated from gross weight.

⁶Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2015^{1,2}

(Metric tons, cobalt content)

Country	Capacity
Australia	6,700
Belgium	1,500
Brazil	3,000 ^e
Canada	6,520 ^e
China	50,000 ^e
Congo (Kinshasa)	9,050 ^e
Finland	13,000 ^e
France	500
India	2,060 ^e
Japan	4,500
Madagascar	5,600
Morocco	2,250
Norway	5,200
Russia	10,000 ^e
South Africa	1,500 ^e
Uganda	720
Zambia	9,600
Total	132,000 ^e

^eEstimated.

¹Data 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.

TABLE 7
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2016–20^{1,2}

Projected year of first production	Country	Project and company	Project type	Principal metal	Ore/feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2016	Australia	Nova Nickel Independence Group NL	new mine and beneficiation plant	nickel	nickel-copper sulfide ore	1,000	Cobalt in nickel concentrate.
2016	Congo (Kinshasa)	Etoile Leach SX-EW ³ plant Chemaf SPRL	new refinery	copper	copper-cobalt tailings	3,800	Cobalt hydroxide.
2016 ^f	Mexico	El Boleo Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (Korean Consortium ⁴ and Baja Mining Corp.)	new mine and refinery	do.	copper-cobalt-zinc-manganese oxide and sulfide ore	1,700	Cobalt cathode.
2016 ^f	Uganda	Kilembe Tibet Hima Industry Co. Ltd. consortium ⁵	reopen former mine	do.	copper-cobalt ore	NA	Cobaltic-pyrite tailings.
2016	Zambia	High Grade Cobalt Matte Metallurgy Chambishi Copper Smelter Ltd. (China Nonferrous Mining Corp. Ltd. and Yunnan Copper Industry Group Co. Ltd.) and Hunan Shijiyintianxinye Technology Co., Ltd.	adapt existing smelter	cobalt	high-grade cobalt matte	475 ⁶	NA.
2016	Do.	Munali nickel mine Consolidated Nickel Mines plc	restart production from existing mine	nickel	nickel-copper-cobalt-platinum-group metals sulfide ore	160	Cobalt in nickel concentrate.
2016 ^f	Do.	Synclinorium Mopani Copper Mines Plc (Glencore plc, First Quantum Minerals Ltd., and ZCCM Investment Holdings Plc)	expansion of existing mine	copper	copper-cobalt ore	NA	Copper-cobalt ore.
2017 ^e	Australia	Rocklands Group Copper, stage 1 CuDeco Ltd.	new mine and beneficiation plant	do.	copper-cobalt-gold oxide and sulfide ore	600 ^{e,6}	Cobaltic-pyrite concentrate.
2017	Canada	NICO Fortune Minerals Ltd.	new mine, relocated and refurbished beneficiation plant, and refinery	gold	gold-cobalt-bismuth-copper ore	1,860	Cobalt sulfate and other cobalt salts.
2017	Congo (Kinshasa)	COMMUS (Kolwezi Copper Mine) La Compagnie Minière de Musonoie Global SAS [Jin Cheng Mining Ltd. (Zijin Mining Group Co., Ltd.), La Générale des Carrières et des Mines SARL (Gécamines), and Zhejiang Huayou Cobalt Co., Ltd.]	new mine	copper	copper-cobalt ore	NA	NA.
2017 ^e	Turkey	Caldag Caldag Nikel Madencilik San. ve Tic A. Ş.	mine, atmospheric tank leach processing plant, and refinery	nickel	nickel-cobalt laterite ore	900	Cobalt cathode.
2018 ^e	Australia	Esperance Nickel Sulphate Plant Alpha Fine Chemicals Ltd.	new refinery	do.	nickel-cobalt hydroxide	100 ^e	Cobalt carbonate.

See footnotes at end of table.

TABLE 7—Continued
 COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2016–20^{1,2}

Projected year of first production	Country	Project and company	Project type	Principal metal	Ore/feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2018	Congo (Kinshasa)	SX–EW ³ copper smelter near Kolwezi Chinalco Yunnan Copper Resources Ltd.	new refinery	copper	copper-cobalt oxide ore	NA	Cobalt hydroxide.
2018 ^e	Do.	Metalkol RTR [Roan Tailings Reclamation (formerly Kolwezi tailings)], phase 1 Eurasian Resources Group, La Générale des Carrières et des Mines SARL (Gécamines), and Government of Congo (Kinshasa)	do.	do.	copper-cobalt tailings	14,000	Do.
2018 ^e	Do.	Project Minier, stage 2 La Sino-Congolaise des Mines S.A. (Sicomines) [China Railway Group Ltd., La Générale des Carrières et des Mines SARL (Gécamines), Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.]	expansion of new mine and beneficiation plant; add new processing plant	do.	copper-cobalt ore	4,600 ^e	Do.
2018 ^e	United States (Idaho)	Idaho Cobalt Formation Metals Inc.	new mine and refinery	cobalt	stratiform cobalt-copper-gold ore	1,260 ⁶	Cobalt sulfate.
2018	Zambia	Chambishi Southeast Mine NFC Africa Mining Plc (China Nonferrous Mining Corp. Ltd. and ZCCM Investment Holdings Plc)	new mine	copper	copper-cobalt ore	NA	Copper-cobalt concentrate.
2019 ^f	United States (Minnesota)	NorthMet, phase 1 PolyMet Mining Corp.	new mine and beneficiation plant	do.	copper-nickel-platinum-group metals sulfide ore	360	Cobalt in nickel concentrate.

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

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

²Projects in feasibility or later stages of development in 2015. Actual startup dates may be postponed owing to economic or other factors. Additional projects might produce cobalt by 2020, but not enough information was available to include them.

³SX–EW solvent extraction–electrowinning.

⁴The Korean consortium comprises the following companies: Korea Resources Corp., L.S. Nikko Copper Inc., Hyundai Hysco Co. Ltd., SK Networks Co. Ltd., and Iljin Copper Foil Co. Ltd.

⁵The consortium comprises the following companies: Chinalco Luoyang Copper (Aluminum Corp. of China Ltd.), Dongfang Electric Corp., Shanghai Baosteel Group Corp., Tibet Hima Industry Co. Ltd., and Yunnan Copper Industry Co. Ltd.

⁶Average production.

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

(Metric tons, cobalt content)

Country ³	2011	2012	2013	2014	2015 ^e
Australia ⁴	3,848	5,870	6,410	5,978	6,000
Botswana ⁵	149	195	248	196	316 ⁶
Brazil	3,623	2,900	3,500	3,828 ^{r,p}	3,800
Canada ⁷	6,836	6,676	7,168	6,907 ^r	6,904 ^{p,6}
China ^e	6,800	7,500	7,200	7,700 ^r	7,700
Congo (Kinshasa) ^{e,8}	59,000	52,000 ^r	56,000	61,000 ^r	63,000
Cuba ^{e,9}	5,100	4,900	4,200	3,700	4,300
Finland ^e	500	635	750	770	440
Indonesia ^{e,10}	1,600	1,700	1,700	1,300	1,300
Madagascar ^{e,11}	500	630	2,200	3,100	3,700
Morocco ^{e,12}	2,160	2,000	2,000	2,150 ^r	2,600
New Caledonia ^{e,13}	3,100	2,670	3,190	4,040	3,680
Papua New Guinea ¹⁴	--	469	1,013	2,134	2,505 ⁶
Philippines ^{e,15}	2,000	2,700	2,800 ^r	4,600	4,300
Russia ^{e,16}	6,100	6,300	6,300	6,300	6,200
South Africa ^e	1,600	2,500	3,000	3,000	3,000
United States ^{e,16,17}	--	--	--	120	760
Vietnam	--	--	25 ^e	223	277 ⁶
Zambia ¹⁸	7,702	5,435	5,919	4,600 ^{r,c}	4,600
Zimbabwe ¹⁹	174	195	319	358	360
Total ^e	111,000	105,000 ^r	114,000	122,000 ^r	126,000

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

¹Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Includes data available through May 24, 2017. Figures 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 and Turkey are known to produce ores that contain cobalt, but information is inadequate to make reliable estimates of production. Poland produced copper ore containing 1,500 to 5,000 metric tons per year of cobalt, which was not recovered. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

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

⁵Reported cobalt content of pelletized nickel-copper matte.

⁶Reported figure.

⁷Assay content of cobalt in concentrates produced.

⁸Cobalt content of concentrates, tailings, and slags.

⁹Determined from reported cobalt content of nickel-cobalt sulfide production and estimated cobalt content of ammoniacal liquor production.

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

¹¹Data for 2012–15 are estimated cobalt content of reported mixed sulfide production.

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.

¹⁸Data for 2011–13 were reported by the Bank of Zambia.

¹⁹Data for 2011–14 were reported by the Zimbabwe National Statistics Agency.

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

(Metric tons, cobalt content)

Country and form	2011	2012	2013	2014	2015
Australia, metal powder and oxide hydroxide ³	4,722	4,859 ⁴	4,981	5,419	5,150
Belgium, metal powder, oxide, hydroxide ^{3,5}	3,187	4,200	5,415	5,850	6,306
Brazil, metal	1,614	1,750	1,871	1,350 ^p	1,300
Canada, metal, metal powder, oxide	6,038	5,994	5,602 ^r	5,491 ^r	4,072
China, metal, metal powder, oxide, salts ^{e,3,6}	35,000	29,800	36,100	39,300	48,700
Congo (Kinshasa), metal ⁷	3,103	3,021	2,777 ^r	2,859 ^r	3,141
Finland, metal powder and salts ⁸	10,627	10,562	10,798	12,551	9,615
France, chloride ³	354	326	308	219	133
India, metal and salts ³	1,299	800	295	100	150
Japan, metal ³	2,007	2,542	2,747	3,654	4,259
Madagascar, metal powder	--	493	2,083	2,915	3,464
Morocco, metal and oxide	1,788	1,314	1,353	1,391	1,722
Norway, metal ⁹	3,067	2,969	3,348	3,600 ^{r,e}	3,100
Russia, metal ³	2,337	2,186	2,368	2,302	2,040
South Africa, metal powder and sulfate	862	1,102	1,294	1,332	1,300
Uganda, metal ³	661	556	376	--	--
Zambia, metal ³	5,749 ^{r,10}	5,669 ^{r,10}	5,000	4,317	2,997
Total	82,400	78,100	86,700 ^r	92,700 ^r	97,400

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

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Includes data available through May 24, 2017. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

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

⁴Production reported by the Cobalt Development Institute and Glencore International AG.

⁵Production from n.v. Umicore s.a.; includes production from China that is not otherwise included in this table.

⁶Production from domestic and imported ores, concentrates, and intermediate materials; excludes production by n.v. Umicore s.a. that is included under Belgium.

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

⁸Production reported by the Geological Survey of Finland.

⁹Data for 2011–12 reported by Xstrata plc; data for 2013–15 reported by the Geological Survey of Norway.

¹⁰Data for 2011–12 include production reported by Zambian Chamber of Mines.