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COBALT [ADVANCE RELEASE]

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Cobalt

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In 2018, the United States did not refine cobalt ores nor concentrates. World production of refined cobalt increased by 6% to 125,000 metric tons (t) (table 8). The increase was mainly the result of higher production in China, where two-thirds of the world's refined cobalt was produced. World cobalt mine production increased by 18% to 148,000 t (table 7). Congo (Kinshasa) remained the leading producer of mined cobalt, supplying 70% of world production, followed by Russia, Australia, the Philippines, Canada, and Cuba. 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 as an intermediate product from the mining and refining of platinum-group-metal (PGM) ore in Montana. No cobalt has been sold from the National Defense Stockpile (NDS) since 2009. Salient U.S. and world cobalt statistics for 2014–18 are listed in table 1.

There were multiple estimates of world consumption of refined cobalt. According to the Cobalt Institute (2019), preliminary trade data indicated that, in 2018, world apparent consumption of refined cobalt increased slightly to about 125,000 t from approximately 123,000 t in 2017. Beijing Antaike Information Development Co., Ltd. (Minor Metals Monthly, 2019) estimated an 11.5% increase to 126,000 t. Darton Commodities Ltd. (2019, p. 4) estimated a 6.6% increase in consumption of refined cobalt to 111,300 t, driven mainly by increased consumption in rechargeable batteries for electric vehicles. Based on their estimate of refined cobalt production in 2018, Darton Commodities estimated a surplus of about 3,000 t of refined cobalt, which led to a downward trend in weekly prices from May through December.

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 in the chemical and petroleum industries; drying agents for inks, paints, and varnishes; dyes and pigments; glass decolorizers; ground coats for porcelain enamels; humidity indicators; magnetic recording media; rubber adhesion promoters for steel-belted radial tires; and as a component of vitamin B12.

Legislation and Government Programs

In May, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 mineral commodities, including cobalt (U.S. Department of the Interior, Office of the Secretary, 2018). The list was developed to serve as an initial focus, pursuant to Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (Trump, 2017).

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, did not sell or ship cobalt in 2018. During the calendar year, the DLA Strategic Materials acquired 210 kilograms (kg) of lithium-cobalt oxide (LCO) and approximately 3 t of cobalt alloy. The Annual Materials Plan for fiscal year 2019 (October 1, 2018, through September 30, 2019), which represented the maximum amounts of materials that DLA Strategic Materials could buy or sell during the year, provided for acquisitions totaling 19 t of lithium-ion battery precursor materials. Calendar yearend NDS inventories of cobalt materials are listed in table 1 (Defense Logistics Agency Strategic Materials, 2018).

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, MI. In 2018, the Eagle Mine produced nickel concentrate containing 17,573 t of nickel and an estimated 490 t of cobalt (22,081 t of nickel and an estimated 640 t of cobalt in 2017). The decrease in production in 2018 was attributed to planned mine sequencing. Lundin continued to develop an access ramp for the nearby Eagle East ore body, from which the first ore production was expected in late 2019. The concentrates were sent by rail to smelters in North America or to ports for shipment overseas (Lundin Mining Corp., 2019a, p. 37; 2019b, p. 1, 17).

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

Missouri Cobalt, LLC was created by executives from an environmental remediation firm and a financial service organization to buy the Madison Mine near Fredericktown, Madison County, MO, from Denver-based Anschutz Mining Corp. Missouri Cobalt planned to remediate the site and restart mining operations as part of the U.S. Environmental Protection Agency's Superfund Redevelopment Initiative. The company planned to begin production by reprocessing tailings from prior mining of lead and other metals to recover cobalt, copper, and nickel in a bulk mineral concentrate (Barker, 2018; U.S. Environmental Protection Agency, 2019).

By yearend 2018, PolyMet Mining Corp. had received all permits from the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency for its NorthMet copper-nickel-cobalt project and issued an updated technical report on the project. Phase 1 of the project consisted of open pit mining of the NorthMet polymetallic deposit in the Duluth

Complex of northeastern Minnesota and production of a copper concentrate and a nickel concentrate that contained cobalt at PolyMet's Erie Plant approximately 10 kilometers (km) west of the ore body. During the first 5 years at full production, NorthMet was expected to produce approximately 150 metric tons per year (t/yr) of cobalt. In early 2019, PolyMet received the Federal record of decision and wetlands permit from the U.S. Army Corps of Engineers, which were the last key permits and approvals needed to construct and operate the project. PolyMet continued to work on construction financing and forecast that construction and rampup to commercial production would take 24 to 30 months after receiving funding (PolyMet Mining Corp., 2019, p. 5–6, 22, 30, 32).

During the year, eCobalt Solutions Inc. continued with preconstruction activities at its Idaho Cobalt project mine and mill site. The company also worked on a revised feasibility study for the project, which would consist of an underground cobalt-copper-gold mine and beneficiation plant approximately 42 km west of Salmon in Lemhi County, ID. eCobalt was evaluating two product options—a low-arsenic cobalt concentrate and a second type of cobalt concentrate, which might reduce capital and operating costs for the plant. In addition, eCobalt identified the potential to increase the targeted production rate by 50%, from an average of approximately 1,100 t/yr of cobalt to approximately 1,600 t/yr of cobalt (eCobalt Solutions Inc., 2019, p. 11–12).

In June, First Cobalt Corp. (Canada) acquired U.S. Cobalt Inc. and its Iron Creek copper-cobalt exploration property in the Idaho Cobalt Belt in Lemhi County, ID. Future concentrate production from this property was a potential feedstock for First Cobalt's cobalt refinery near North Cobalt in Ontario, Canada (First Cobalt Corp., 2019a, p. 2–3).

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 2018 was essentially the same as that in 2017 (table 1). Metallurgical and chemical industries each used essentially the same amount of cobalt as they did in 2017. Reported consumption statistics were derived by the USGS from voluntary surveys of U.S. operations. Most of the cobalt chemical-use data were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as cemented carbide, magnetic alloy, and superalloy producers. For this survey, about 50 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 2 include estimates based on prior reports or industry trends to account for nonrespondents.

U.S. apparent consumption for 2018, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 15% less than revised apparent consumption in 2017 (table 1). The decrease was primarily a result of higher exports in 2018 compared with those in 2017.

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 $37.43 per pound, 39% more than that in 2017 (table 1). During the first 5 months of the year, the Platts price continued the upward trend that began in early 2016. The Platts price rose from $36.00 to $37.00 per pound in early January 2018 to highs of $44.00 to $45.00 per pound in late March and early May—the highest levels since June 2008. The increase was attributed to continued purchases by investment funds and investors during a tight market for refined cobalt metal, which led to increases in mined, processed, and refined cobalt production. This resulted in oversupply of cobalt intermediates, refined cobalt, and battery precursor materials, so that from mid-May onward, the Platts price generally trended downward until it reached a low of $29.00 to $30.00 per pound in late December (Darton Commodities Ltd., 2019, p. 1, 4).

Cobalt metal with a minimum of 99.8% cobalt in the form of broken and cut cathode, ingots, rounds, and coarse-grain metal powder was traded on the London Metal Exchange Ltd. (LME). Sherritt International Corp. (2019, p. 10) reported that the amount of cobalt traded on the LME in 2018 decreased by 9% to 12,932 t. This represented only about 10% of global refined cobalt production (table 8). Sherritt and the LME attributed the LME cobalt contract's continued illiquidity as the reason for it remaining a secondary pricing mechanism (Radford, 2018). The annual average mean of cash-buyer and cash-seller prices and yearend LME inventory levels are listed in table 1.

In 2018, the LME reportedly decided to not pursue a plan to add a cobalt sulfate contract for the electric vehicle battery supply chain, because pricing for cobalt sulfate historically had been based on cobalt metal prices and not on fundamentals of the cobalt sulfate market. The LME was considering adding a cash-settled cobalt metal contract, however. In contrast to the existing cobalt metal contract, which delivered physical metal, the cash-settled contract would transfer the cash value of the physical metal based on a reference price from a price-reporting agency (Desai, 2018; Radford, 2018). In 2018, the LME proposed new sourcing requirements for its listed metal brands (as described in the "World Review" section).

Cobalt also was traded on the Chinese Stainless Steel Exchange (CSSE) (Wuxi, Jiangsu Province). During 2018, CSSE cobalt inventories reportedly were drawn down from more than 1,000 t in March to slightly more than 300 t in June to 136 t in September (Behre Dolbear, 2018; Radford and Zou, 2018).

Cobalt 27 Capital Corp. (Canada) was a resource trading company with the objective of facilitating investment in the cobalt market. The company acquired and held physical cobalt, entered into streaming contracts and net smelter return royalty agreements, and (or) invested in mines or early stage exploration and development projects of deposits containing cobalt. At yearend, Cobalt 27 held 2,905 t of cobalt stored in LME warehouses in the United States and Europe. During the year, the company entered into a streaming contract with a subsidiary of Vale S.A. for cobalt from the Voisey's Bay operation in Canada and was in the process of acquiring Highlands Pacific Ltd., which had an 8.56% share in the Ramu nickel-cobalt operation in Papua New Guinea. By early 2019, Cobalt 27 had acquired royalty agreements pertaining to two properties in Australia (an exploration-stage nickel-cobalt-scandium property and a development-stage scandium-nickel-cobalt property) and nine exploration- or development-stage properties in Canada (one nickel-cobalt property in Quebec, four cobalt-silver properties in Ontario, two silver-lead-zinc-cobalt properties in Yukon, and one copper-zinc-cobalt property and one nickel-cobalt property in British Columbia) (Cobalt 27 Capital Corp., 2019, p. 3, 7–10).

Foreign Trade

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic production to meet demand. Net import reliance is defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were originally imported or produced in the United States. In 2018, net import reliance as a percentage of apparent consumption for cobalt was 64%. Because U.S. cobalt mine production was exported to be refined, this indicates that 64% of U.S. cobalt supply was from imports and stock releases of refined cobalt and 36% 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 2018, the United States imported 11,800 t of cobalt contained in metal and chemical compounds, valued at $755 million, slightly less than the 11,900 t imported in 2017 (table 3). On the basis of cobalt content, 10 countries supplied 93% of U.S. imports in 2018. Canada was the leading supplier, followed by Japan, Finland, Norway, China, Madagascar, Australia, Russia, Belgium, and the United Kingdom (table 4). The U.S. Census Bureau also reported U.S. imports of the following materials: cobalt waste and scrap (2,430 t gross weight, valued at $41.1 million), unwrought cobalt alloys (565 t gross weight, valued at $31.9 million), and wrought cobalt and cobalt articles (341 t gross weight, valued at $44.6 million).

U.S. exports of unwrought cobalt and cobalt contained in chemicals were 6,960 t, valued at $180 million, 22% more than the 5,710 t (revised) exported in 2017. On the basis of cobalt content, Canada was the leading destination for these exports, followed by Ireland, France, the United Kingdom, Taiwan, Germany, the Netherlands, and Brazil (table 5). The U.S. Census Bureau also reported that the United States exported 1,160 t gross weight of wrought metal and cobalt articles valued at $127 million.

World Review

World cobalt mine and refinery production each increased in 2018 compared with production in 2017. The increases were the result of a 24,000-t increase in estimated mine production in Congo (Kinshasa), the leading global producer of mined cobalt (table 7), and an 8,100-t increase in estimated refinery production in China, the leading global producer of refined cobalt (table 8).

Cobalt was produced as a byproduct of copper, nickel, and other metals, and as a primary product (the principal product of a mining or processing operation). Non-byproduct (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 or tailings in Congo (Kinshasa)], which were processed primarily to recover cobalt.

Refinery capacity by country is listed in table 6. Depending on their vertical integration and the processes used, these plants consumed mainly ores, concentrates, and (or) partially refined intermediate materials; they also may have consumed some secondary (scrap) materials. The table does not include plants that reprocessed refined cobalt, plants that used scrap as their main source of feed, or plants that produced a partially refined intermediate material that required further refining by another plant.

Companies throughout the cobalt supply chain (mining, processing, and refining companies; trading firms; and end users, from producers of materials to manufacturers of products such as consumer electronics and vehicles) and nongovernmental organizations and other stakeholders continued to focus attention on the sources of cobalt-containing raw materials and components regarding ethical and sustainable production. Several initiatives have been launched in recent years to promote responsible sourcing of cobalt, particularly with regard to artisanal mining in Congo (Kinshasa) (Amoruso, 2017; Darton Commodities Ltd., 2019, p. 38–39).

In 2018, at least five new projects, many on a pilot scale, were launched. Three projects—(1) RCS Global Group's Better Cobalt project, (2) a project by Dorae Inc., and (3) a joint venture between Cobalt Blockchain Inc. and DLT Labs Inc.—planned to use blockchain technology to electronically tag cobalt produced from selected artisanal or semi-mechanized mines and trace the cobalt throughout the supply chain. A fourth project was a partnership between Trafigura Group, Chemaf SARL, a cooperative for artisanal and small-scale mining, and the international nongovernmental organization Pact. Located at the Mutoshi Mine in Kolwezi, this project intended to implement a formal strategy for artisanal mining within a defined area of a mining concession to meet international responsible sourcing guidelines. This project was designed as a

commercial sourcing agreement between the artisanal mining cooperative and the cobalt mining and processing company. In a fifth project, BMW Group, BASF SE, Samsung SDI, Samsung Electronics, and Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH planned to identify ways to improve living and working conditions at one artisanal mine (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, 2018; Hotter, 2018; RCS Global Group, 2018; Darton Commodities Ltd., 2019, p. 38–39; Johansson de Silva and others, 2019, p. 6, 12–13).

This focus on ethical and sustainable cobalt supplies extended to the LME, which proposed new requirements for responsible sourcing of its listed metal brands that would be aligned with the Organisation for Economic Co-operation and Development's "Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas." Cobalt and tin were categorized as high-focus metals because they were generally recognized to be at higher risk of originating from areas with sourcing concerns than other metals. The LME wanted cobalt and tin producers to identify standards of responsible sourcing by the fourth quarter of 2019 and would require full compliance with the standards by the end of 2020. Noncompliant brands could be delisted. For cobalt, the LME proposed a transitional provision, whereby cobalt brands negatively affecting LME pricing might be subject to earlier action (London Metal Exchange Ltd., 2018).

Australia.—In 2018, cobalt mine production as a byproduct of nickel mining in Western Australia decreased by 3% and Australian production of refined cobalt increased by 7% (tables 7, 8).

BHP Group Ltd.'s Nickel West operations in Western Australia consisted of open pit and underground nickel sulfide mines; concentrators, which processed ores mined by BHP 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 2018, BHP produced 920 t of salable cobalt (full-year data for 2017 were not available). During the year, BHP began preparatory work on a 100,000-t/yr nickel sulfate plant at its Kwinana refinery and continued with solvent extraction test work for a potential cobalt sulfate circuit at the plant (BHP Group Ltd., 2018, p. 59, 241–242; 2019, p. 10).

Independence Group NL owned the Nova underground nickel-copper-cobalt sulfide mine east of Norseman, Western Australia. During the calendar year, the company ramped up production to 969 t of cobalt in nickel concentrate, an increase from 400 t in 2017. Production from the first 3 years of operation was committed for sale to BHP's Nickel West operation and to Glencore plc. During the year, Independence Group studied the potential to refine its nickel concentrate using a hydrometallurgical process to produce nickel and cobalt sulfates. Production guidance for the fiscal year beginning July 1, 2018, was 850 to 950 t of cobalt in concentrate (Independence Group NL, 2018a, p. 14, 16–17; 2018b, p. 3; 2019, p. 16).

Minara Resources Ltd. (Glencore plc) produced 3,200 t of cobalt metal at its Murrin Murrin nickel-cobalt laterite mining and pressure-acid-leaching operation in Western Australia, 7% more than the 3,000 t produced in 2017. Production in 2017 was less because of a scheduled maintenance shutdown during that year. In 2017 and 2018, approximately 300 t of Murrin Murrin's production was from third-party feed (Glencore plc, 2019, p. 79, 225).

First Quantum Minerals Ltd. (Canada) kept its Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant in Western Australia on care-and-maintenance status throughout the year. The company planned to monitor nickel market conditions to determine when it might restart production. In 2017, the plant produced intermediate nickel-cobalt hydroxide containing 17,837 t of nickel and an estimated 620 t of cobalt (First Quantum Minerals Ltd., 2019, p. 19).

In December, Panoramic Resources Ltd. restarted production at its underground Savannah nickel-copper-cobalt sulfide mine in Western Australia. Concentrate from the operation was to be sold to Jinchuan Group Co., Ltd. and Sino Nickel Pty. Ltd. under a 4-year agreement. In October, Western Areas Ltd. announced that it planned to develop the Odysseus project at its Cosmos nickel sulfide complex in Western Australia. During a mine life of 10 years, the mine was expected to produce 2,400 t of cobalt in nickel concentrate (Western Areas Ltd., 2018, p. 1–2; Panoramic Resources Ltd., 2019).

Belgium.—Darton Commodities Ltd. (2019, p. 8, 16) estimated that Umicore's cobalt production at its Olen refinery in 2018 was 4% higher than production in 2017. The refinery produced cobalt salts and oxides; its feed included cobalt recovered by Umicore's recycling operation in Hoboken. In addition to the Olen refinery, which reportedly was upgraded and expanded in mid-2018, 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 (2019), Umicore produced 9% less refined cobalt from its two refineries in 2018 than it produced in 2017. The company also had cobalt processing plants, which made specialty chemicals and (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. In 2018, Umicore announced a plan to build a plant in Nysa, Poland, to manufacture battery cathode materials for the European automotive market (Umicore N.V./S.A., 2018, undated).

Brazil.—Companhia Brasileira de Alumínio (CBA) (an investee of Votorantim S.A.) owned the nickel-cobalt laterite mining and processing operation in Niquelandia, Goias State, and refinery at Sao Miguel Paulista, Sao Paulo State. Mining had been suspended since 2016 in response to low nickel prices. In 2018, CBA produced 8 t of cobalt from stockpiled ore, down from 46 t in 2017 (table 8) (Companhia Brasileira de Alumínio, 2019, p. 9).

Canada.—Vale's global cobalt production was 5,093 t in 2018, 12% less than the 5,811 t produced in 2017. Vale produced 1,288 t (1,675 t in 2017) of refined cobalt metal at its Port Colborne, Ontario, refinery; 1,630 t (1,231 t in 2017) of refined cobalt metal at its Long Harbour, Newfoundland and Labrador, refinery; 2,105 t (2,780 t in 2017) of cobalt in a cobalt intermediate product at its nickel operation in New Caledonia; and 70 t (125 t in 2017) of cobalt contained in other

intermediate products such as nickel concentrates. Vale's cobalt supply was produced 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 520 t (840 t in 2017) of cobalt came from Sudbury, 198 t (138 t in 2017) came from Thompson, 1,902 t (1,829 t in 2017) came from Voisey's Bay, 2,104 t (2,780 t in 2017) came from New Caledonia, and 371 t (224 t in 2017) came from external sources, including 173 t of cobalt in ore from PT Vale Indonesia Tbk (6 t in 2017) (Vale S.A., 2019, p. 60).

In 2018, all of Vale's Voisey's Bay nickel concentrate was shipped to its hydrometallurgical refinery in Long Harbour, where cobalt was produced in the form of electrolytic metal rounds. In June, Vale established a cobalt streaming transaction with Wheaton Precious Metals Corp. and Cobalt 27. Vale agreed to sell 75% of future cobalt production from Voisey's Bay ore to Wheaton and Cobalt 27, starting January 1, 2021, for $690 million and payments averaging 20% of cobalt prices upon delivery. Vale planned to use the funds to complete the Voisey's Bay underground mine extension project, which would extend the operation's mine life and increase average annual production to an estimated 45,000 t of nickel, 20,000 t of copper, and 2,600 t of cobalt (Vale S.A., 2019, p. 14, 82).

During 2018, Vale completed the shutdown of smelting and refining operations at Thompson, owing to Canadian sulfur dioxide emission standards that came into effect in 2015. Since the second half of 2018, most of the nickel concentrate produced at Thompson was sent to Sudbury for refining (Vale S.A., 2019, p. 50).

Glencore reported that 900 t of the cobalt produced at its Nikkelverk refinery in Norway originated from concentrates produced from its mines at Sudbury, Ontario, and Raglan, Quebec (800 t in 2017) (Glencore plc, 2019, p. 225).

The Fort Saskatchewan refinery, a joint venture of Sherritt and General Nickel Co. S.A., produced 3,234 t of cobalt as metal powder and briquettes in 2018 (3,601 t in 2017). The decrease was attributed to a disruption in the supply of hydrogen sulfide needed for refining, reduced availability of intermediate nickel-cobalt sulfide because of high rainfall in Cuba, and delays in rail transportation to the refinery. Approximately 89% of the cobalt originated from Moa, Cuba, and the remainder was from purchased materials. As a result of a United States embargo on imports of products originating from Cuba, cobalt and nickel produced by Sherritt could not be sold to customers in the United States (Sherritt International Corp., 2019, p. 3, 11, 55–56).

During the year, First Cobalt evaluated capital requirements, operating costs, permit renewal timelines, potential feedstock options, and offtake opportunities needed to restart production from its cobalt refinery near North Cobalt in Ontario, Canada. The refinery had been on care-and-maintenance status since 2015, prior to which it operated intermittently under several former owners following commissioning in 1996. First Cobalt forecast that the refinery could restart production 18 to 24 months after a feedstock was selected (First Cobalt Corp., 2019a, p. 3; 2019b, p. 12).

China.—China was the world's leading producer and consumer of refined cobalt. In 2018, China's total production, including an estimate for Umicore's Ganzhou Yi Hao plant, increased by 11% from that in 2017 and was estimated to constitute about two-thirds of world refined cobalt production (table 8). Most production was in the form of cobalt salts (84%); the remainder was metal (10%) and metal powder (6%). China's consumption of refined cobalt increased to 64,000 t, 11% more than that in 2017; 81% of 2018 consumption was used to make cathode materials for rechargeable batteries (CNIA Cobalt Branch, 2019, p. 4–5; Darton Commodities Ltd., 2019, p. 8).

Numerous companies refined and (or) processed cobalt in China. In 2018, the leading producers of refined cobalt were Zhejiang Huayou Cobalt Co., Ltd., Shenzhen GEM High-Tech Co. Ltd. (including subsidiary Jiangsu Cobalt Nickel Metal Co. Ltd.), and Jinchuan Group Co. Ltd., listed in decreasing order of estimated production. Only a small portion of China's cobalt production originated from domestic mines. Most of the refinery production used imported cobalt intermediate chemical compounds, the majority of which was sourced from Congo (Kinshasa). Although higher than those in 2017, China's imports of cobalt concentrates in 2018 had decreased in recent years as more concentrates were 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 increasing amounts of cobalt from scrap. In 2018, despite China's supply of cobalt raw materials increasing from that in 2017, raw material inventories were estimated to be drawn down by about 5,200 t of contained cobalt to balance the refineries' supply and consumption of raw materials (CNIA Cobalt Branch, 2019, p. 3; Darton Commodities Ltd., 2019, p. 8, 48).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt and was estimated to represent 70% of global production (table 7). Most of the country's cobalt mine production was from copper-cobalt ores mined by industrial or mechanized methods. A lesser amount was gathered by tens of thousands of artisanal miners by handpicking cobalt-rich ores. Artisanal mining filled the role of a swing producer, increasing during periods of supply deficits and higher prices. Although analysts agreed that artisanal mining increased in 2018 compared with that in 2017, their estimates of the amount of cobalt produced by artisanal methods in 2018 varied widely, from 15,000 t to 17,000 t of contained cobalt to one forecast of nearly 30,000 t of contained cobalt (Heppel, 2018; Darton Commodities Ltd., 2019, p. 4, 35, 37–38).

Most of the ores and concentrates produced in Congo (Kinshasa) were processed domestically into 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 domestically into cobalt metal (Darton Commodities Ltd., 2019, p. 35–36; Division Provinciale des Mines du Haut-Katanga, 2019).

The state-owned mining company La Générale des Carrières et des Mines SA (Gécamines) held a minority share in most of the copper-cobalt operations in Congo (Kinshasa) and had been the sole producer of refined cobalt in the country since late

2015, when Kamoto Copper Company SA (KCC) halted metal production at its Luilu cobalt refinery. In 2018, Gécamines was estimated to have produced 60 t of refined cobalt at its Shituru refinery in Likasi (based on reported exports), down from 120 t in 2017 (Katanga Mining Ltd., 2016, p. 1–2; Division Provinciale des Mines du Haut-Katanga, 2019).

In 2018, the Government of Congo (Kinshasa) undertook several measures with the objective of increasing future revenues from cobalt production. For example, Gécamines planned to renegotiate its joint-venture contracts with international mining companies to give the Government shares of production and to increase Gécamines' stakes in the ventures. Congo (Kinshasa)'s parliament revised the country's mining code and cobalt was declared a strategic substance. As a result, royalties on cobalt paid by mining companies increased to 10% from 2%, a new super profits tax of 50% was introduced on profits exceeding 25% of those forecast in the project feasibility study, and the stability period during which taxes and customs could not be modified was reduced to 5 years from 10 years (Aglionby and Hume, 2018; DLA Piper International LLP, 2018; Ross, 2018).

Mutanda Mining SPRL (Glencore, 100%) mined copper-cobalt oxide ore from open pits near Kolwezi and produced a record-high 27,300 t of cobalt in concentrate and crude cobalt hydroxide, 14% more than the 23,900 t produced in 2017 (Glencore plc, 2019, p. 221).

Tenke Fungurume Mining S.A.R.L. [China Molybdenum Co., Ltd. (CMOC), BHR Equity Investment Fund Management Co. (BHR Partners), and Gécamines] mined copper-cobalt ore, which it processed onsite to produce 18,747 t of cobalt in crude cobalt hydroxide, 14% more than the 16,419 t produced in 2017. The increased production was attributed to investments to optimize production. Most of the hydroxide was sold to Freeport Cobalt Oy's Kokkola refinery in Finland under a long-term agreement; the remainder was sold to refiners in China. CMOC forecast a cobalt production volume of 16,500 to 19,000 t of cobalt in hydroxide in 2019 (China Molybdenum Co., Ltd., 2019, p. 18–19, 55, 104; Darton Commodities Ltd., 2019, p. 27–28).

KCC [Katanga Mining Ltd. (a subsidiary of Glencore plc), Gécamines, and La Société Immobilière du Congo] restarted cobalt processing as part of commissioning the whole ore leach project at its copper-cobalt mining and refining operation in Lualaba Province and produced 11,112 t of cobalt in hydroxide. The company also worked on a cobalt debottlenecking project, which included adding a magnesium oxide reagent plant within the cobalt circuit, new filter presses, and new cobalt hydroxide dryers. The project was intended to align cobalt-processing capacity with the life-of-mine plan to produce an average of 30,000 t/yr of cobalt in hydroxide and a maximum processing capacity of 40,000 t/yr of cobalt in hydroxide. In November, KCC temporarily suspended exports and sales of its cobalt hydroxide after detecting uranium levels that exceeded allowable regulatory limits for export. KCC began a feasibility study on constructing an ion exchange plant to remove uranium from the hydroxide and investigated various interim operational and regulatory options to resume exports and sales. Glencore was KCC's majority shareholder and had life-of-mine offtake agreements for all KCC's copper and cobalt output (Katanga Mining Ltd., 2019, p. 4–5, 14, 20).

Boss Mining SPRL [Eurasian Resources Group S.a.r.l. (ERG), 40% of which is owned by the Government of Kazakhstan, and Gécamines] extracted copper-cobalt ore from open pit mines at Mukondo Mountain and Kabolela and tailings generated by past mining operations within its license area. From these materials, Boss Mining produced oxide and sulfide concentrates at its Kakanda concentrator. The company's concentrate production was thought to have stabilized in 2018, after steadily decreasing in recent years because of changes in mineralogy of the ore being mined at the open pits. Boss Mining refined some of the concentrate to copper cathode and byproduct crude cobalt carbonate in Congo (Kinshasa). The remainder was exported to Zambia to be refined at ERG's Chambishi Metals plc plant. In 2018, Boss Mining exported 5,970 t gross weight of cobalt carbonate, 34,600 t gross weight of cobalt concentrate, and 2,320 t gross weight of copper-cobalt concentrate (Darton Commodities Ltd., 2019, p. 33; Division Provinciale des Mines du Haut-Katanga, 2019).

By yearend, ERG had commissioned phase 1 of its Metalkol Roan Tailings Reclamation project and began producing copper cathode and cobalt hydroxide. The project entailed recovering copper and cobalt from tailings deposited in the Kingamyambo Tailings Dam and Musonoi River Valley in Haut Katanga Province during past mining operations. In 2018, Metalkol produced 300 t of contained cobalt in salable cobalt hydroxide. At full operation, Metalkol's phase 1 was expected to produce 14,000 t/yr of cobalt in hydroxide, which would increase to 20,000 t/yr during a phase 2 expansion (Darton Commodities Ltd., 2019, p. 34; 2020, p. 37; Eurasian Resources Group S.a.r.l., 2020, p. 10).

Chemaf SARL (Shalina Resources Ltd., United Arab Emirates) mined copper-cobalt oxide and sulfide ores mainly from its Etoile open pit mine. Concentrate from Etoile was processed to copper cathode and crude cobalt hydroxide at Chemaf's solvent extraction–electrowinning (SX–EW) plants at the mine site and at Usoke in Lubumbashi. In 2018, Chemaf exported 28,056 t gross weight of cobalt hydroxide. Umicore and Samsung SDI reportedly purchased hydroxide from Chemaf. During the year, Chemaf began construction of a copper refinery at its Mutoshi project, which was to include the capacity to produce 16,000 t/yr of cobalt in hydroxide. Part of this project included the Mutoshi artisanal mining pilot project described in the previous discussion on responsible sourcing. Once the pilot project began, all concentrates from Mutoshi were processed exclusively at the Usoke plant and cobalt from Chemaf's mechanized mines was processed at Etoile (Chemaf SARL, 2018; Darton Commodities Ltd., 2019, p. 29–30; Johansson de Silva and others, 2019, p. 34).

Ruashi Mining SPRL [Jinchuan subsidiary Metorex (Proprietary) Ltd. and Gécamines] produced 4,752 t of cobalt in crude cobalt hydroxide from its Ruashi operation east of Lubumbashi, an increase from 4,638 t in 2017. The increase in production was attributed to a higher feed grade and higher cobalt recovery. The company prioritized cobalt production over copper production at the mine to increase cobalt production during a period of high prices in the first half of the year and processed a significant amount of foreign ore. Ruashi consisted of three open pit copper-cobalt oxide mines and an SX–EW

refinery. The cobalt hydroxide produced was offered for sale on the international market. During the year, Jinchuan studied the feasibility of developing its Musonoi copper-cobalt project near Kolwezi (Jinchuan Group International Resources Co. Ltd., 2019, p. 3, 14–15, 21).

Metal Mines SARL (Nanjing Hanrui Cobalt Co., Ltd.) reportedly expanded the cobalt hydroxide production capacity of its processing plant in Likasi, Haut Katanga Province, to 5,000 t/yr of cobalt in hydroxide. The plant processed copper-cobalt ore from mines leased by Metal Mines as well as some ore from other companies. In 2018, Metal Mines exported 19,600 t gross weight of cobalt hydroxide and 14,800 t gross weight of cobalt concentrate (Darton Commodities Ltd., 2019, p. 30; Division Provinciale des Mines du Haut-Katanga, 2019).

Somika SPRL (Société Minière de Katanga, Vinmart Group, India) produced cobalt hydroxide at its plant in Lubumbashi, Haut-Katanga Province, from copper-cobalt ores sourced from small- and large-scale mining operations. In 2018, the company exported 10,400 t gross weight of cobalt hydroxide, exported 5,430 t gross weight of cobalt concentrate, and sold 6,960 t gross weight of cobalt mineral to the local market (Darton Commodities Ltd., 2019, p. 31–32; Division Provinciale des Mines du Haut-Katanga, 2019).

China Railway Group Ltd. had shares in three copper-cobalt mining and refining operations in Congo (Kinshasa)—La Sino-Congolaise des Mines S.A. (Sicomines) (a joint venture with Gécamines, Sinohydro Corp., and Zhejiang Huayou Cobalt Co., Ltd.), Compagnie Minière de Luisha S.A.S., and La Minière de Kalumbwe Myunga sprl (MKM). In 2018, Sicomines exported 1,630 t gross weight of cobalt hydroxide and 34 t gross weight of cobalt concentrate and MKM exported 3,110 t gross weight of cobalt hydroxide (China Railway Group Ltd., 2019, p. 32; Division Provinciale des Mines du Haut-Katanga, 2019).

Congo Dongfang International Mining SPRL (CDM) (a subsidiary of Zhejiang Huayou Cobalt Co., Ltd.) was responsible for procuring cobalt feed materials for Huayou's refineries in China and produced crude cobalt hydroxide at its La Minière de Kasombo SPRL (MIKAS) hydrometallurgical plant in Lubumbashi. In 2018, CDM and MIKAS exported about 35,400 t gross weight of cobalt hydroxide. The ores and concentrates reportedly were sourced from CDM's mines and other Congolese mining operations, including artisanal miners (Darton Commodities Ltd., 2019, p. 11–12, 28–29; Division Provinciale des Mines du Haut-Katanga, 2019).

Compagnie Minière de Kambove (COMIKA) (Wanbao Mining Ltd. and Gécamines) mined copper-cobalt ore from the open pit Kamoya copper-cobalt mine near Kambove, Haut-Katanga Province. In 2018, COMIKA exported 46,200 t gross weight of copper-cobalt concentrate and 1,460 t gross weight of cobalt hydroxide. Wanbao Mining planned to expand the operation in 2019 (Darton Commodities Ltd., 2019, p. 31; Division Provinciale des Mines du Haut-Katanga, 2019).

The Lualaba Copper Smelter SAS joint venture (LCS) [composed of subsidiaries of China Nonferrous Mining Corp. Ltd. (CNMC) and Yunnan Copper Industry Group Co., Ltd.] began construction of a blister copper smelter. As part of the project, LCS was constructing a "cobalt recycling system" to produce 10,000 t/yr of crude copper-cobalt alloy (China Nonferrous Mining Corp. Ltd., 2019, p. 39).

Société Congolaise du Traitement du Terril de Lubumbashi SAS (STL) (Groupe Forrest International and Gécamines) did not restart production of alliage blanc in 2018. In 2017, STL lost access to its feedstock, the Big Hill slag heap, when Gécamines claimed that the company's cobalt production had exceeded the limit allowed under a contract between Gécamines and trading company Groupement du Terril de Lubumbashi Ltd. (GTL). In mid-2018, Gécamines and GTL resolved their dispute in an agreement that included GTL repairing the smelter's furnace and transferring ownership of STL and the smelter to Gécamines. In return, Gécamines transferred its shares in GTL to Groupe Forrest and paid GTL a compensatory indemnity (Clowes and Wilson, 2017; La Générale des Carrières et des Mines SA and Groupement du Terril de Lubumbashi Ltd., 2018).

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 2018, the sulfide contained 35,125 t of nickel and cobalt (34,595 t in 2017) (Sherritt International Corp., 2019, p. 87).

The Government-owned Empresa Niquelífera Ernesto Che Guevara operation (also known as Punta Gorda) in Moa, Holguin Province, mined and processed nickel-cobalt laterites. The operation was expected to undergo repair and maintenance work, including the purchase of mining equipment, beginning in mid-2018 (Redacción ¡ahora!, 2018). Nickel and cobalt originating in Cuba could not be imported into the United States because of a United States embargo on imports from Cuba (U.S. Code, 2010).

Finland.—According to the Cobalt Institute (2019), in 2018, Freeport Cobalt Oy (Freeport-McMoRan Inc., Lundin, and Gécamines) produced 5% more cobalt at its Kokkola refinery than it produced in 2017. The company produced a wide range of cobalt chemicals and metal powders. In 2018, the main feed for the refinery was crude cobalt hydroxide supplied under a long-term agreement by the Tenke Fungurume operation in Congo (Kinshasa); the refinery also processed cobalt-bearing scrap from the cemented carbide, battery, and catalyst industries. Since 2016, when it sold its share of Tenke Fungurume to China Molybdenum, Freeport-McMoRan has wanted to sell its share in Freeport Cobalt (Darton Commodities Ltd., 2019, p. 13–14; Freeport-McMoRan Inc., 2019, p. 21, 124; Freeport Cobalt Oy, undated).

PJSC MMC Norilsk Nickel (Nornickel, Russia) produced two cobalt products at its Harjavalta nickel refinery—refined cobalt sulfate and an intermediate cobalt sulfate solution. In 2018, most of the refinery's nickel feed was sourced from company operations in Russia (nickel matte from Kola MMC); third-party feed included nickel matte from Boliden AB's Harjavalta smelter and nickel salts from other companies. Nornickel and BASF SE signed an agreement under which Nornickel would supply cobalt and nickel from Harjavalta to BASF for the production of battery cathode materials for the automotive industry in a plant to be built adjacent to the Harjavalta refinery (PJSC MMC Norilsk Nickel, 2019, p. 73, 87, 92).

Boliden's Kevitsa open pit nickel-copper-PGM sulfide mine and beneficiation plant produced nickel concentrate containing 13,948 t of nickel and 591 t of cobalt in 2018 (compared with 13,777 t of nickel and an estimated 587 t of cobalt in 2017). In 2018, Boliden began producing nickel-cobalt concentrate at its underground Kylylahti copper-zinc mine and produced concentrate containing 518 t of nickel and 278 t of cobalt. During the year, Boliden worked to expand production at Kevitsa by 27% by yearend 2020 and evaluated the potential of extending Kylylahti's lifespan. The company's Harjavalta smelter processed nickel concentrates from Kevitsa and elsewhere and sold the resulting nickel matte (Boliden AB, 2019, p. 26, 30, 51, 113, 115).

Terrafame Ltd. [Finnish Minerals Group Ltd. (formerly Terrafame Group Ltd., Government of Finland), Trafigura Ventures V B.V., Galena Private Equity Resources Investment 2 L.P., Galena Private Equity Resources Investment 3 L.P. funds, and Sampo plc] stabilized operations at its polymetallic sulfide mining and bioheap-leaching operation in Sotkamo, central Finland. In 2018, the company produced intermediate nickel-cobalt sulfide containing 27,377 t of nickel and, based on reported nickel and cobalt contents of the sulfide in 2016, an estimated 550 t of cobalt (20,864 t nickel and an estimated 420 t cobalt in 2017). All of the operation's nickel-cobalt and 80% of its zinc was sold by Trafigura Ventures V B.V. under a long-term agreement. During the year, Terrafame decided to build a refinery that would convert its nickel-cobalt sulfide into nickel sulfate and cobalt sulfate for battery applications. The company continued with a feasibility study on the project, conducted basic and detailed engineering, and began earthwork construction (Terrafame Oy, 2017, p. 119; Terrafame Ltd., 2019, p. 10–11, 14–15, 68, 85).

France.—Eramet s.a. produced nickel metal, nickel salts, and cobalt chloride at its Sandouville refinery. The refinery continued to ramp up production following an upgrade necessitated by a planned change in feed composition. Since mid-2017, Eramet had purchased matte from Boliden's Harjavalta smelter under a long-term supply agreement (Thomson Reuters, 2016; Eramet s.a., 2019, p. 47).

India.—According to estimates by the Cobalt Institute (2019), India's cobalt production was unchanged from that in 2017. India's leading cobalt producers, Nicomet Industries Ltd. and Rubamin Ltd., reportedly halted 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., 2019, p. 50–51).

Several companies formed joint ventures to consider developing new mining and (or) high-pressure acid leaching (HPAL) operations to produce nickel-cobalt intermediates or refined nickel and cobalt salts from Indonesian lateritic ores. Joint-venture projects included PT Halmahera Persada Lygend's project on Obi Island and PT Huayue Nickel Cobalt's project in Morowali, Sulawesi Island, which each planned to produce nickel-cobalt hydroxide; Sumitomo and Vale's joint venture in Pomalaa, Sulawesi Island, which planned to produce nickel-cobalt sulfide; and PT QMB New Energy Materials in Morowali, which planned to produce nickel sulfate and cobalt sulfate (Li, 2018; Shah and Peng, 2018).

Japan.—Sumitomo's Niihama nickel refinery in Ehime Prefecture processed intermediate nickel-cobalt sulfides from the Coral Bay Nickel Corp. and Taganito HPAL Nickel Corp. plants in the Philippines, nickel matte from PT Vale in Indonesia, and additional raw materials from elsewhere. The Niihama refinery produced cobalt chloride, most of which was converted to electrolytic cobalt (cobalt cathode) for sale. In 2018, Sumitomo's production of refined cobalt decreased for the second consecutive year, which was attributed to equipment problems at the Taganito plant, following an expansion the previous year (Cobalt Institute, 2019; Darton Commodities Ltd., 2019, p. 17; Sumitomo Metal Mining Co., Ltd., 2019, p. 52, 66).

Sumitomo's Harima refinery in Hyogo Prefecture processed intermediate nickel-cobalt sulfides from Coral Bay Nickel and Taganito to produce cobalt chloride. Some of the cobalt chloride from Harima was sent to Niihama to be converted to metal. Some of Sumitomo's cobalt chloride—from Harima and Niihama—was sent to Sumitomo's Isoura battery materials plant in Niihama and its Sumiko Energy Materials Co., Ltd. plant in Fukushima to produce battery cathode materials (Darton Commodities Ltd., 2019, p. 17; Sumitomo Metal Mining Co., Ltd., 2019, p. 66).

Madagascar.—In 2018, the Ambatovy joint venture (Sumitomo Corp., Korea Resources Corp., and Sherritt) produced 2,852 t of cobalt metal (3,053 t in 2017). Sherritt was the operator of the joint venture, which mined nickel-cobalt laterite ore in east-central Madagascar and transported the ore by pipeline to a processing plant and refinery located near the Port of Toamasina (Sherritt International Corp., 2019, p. 3, 14).

Mexico.—Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (MMB) [Korean Consortium and Camrova Resources Inc. (Canada)] owned and operated the El Boleo project, which consisted of a copper-cobalt-zinc mine and refinery in Baja California Sur. During the year, MMB extracted ore from underground and open pit mines and produced 226 t of refined cobalt, a decrease from the estimated 420 t produced in 2017 (Camrova Resources Inc., 2019, p. 4).

Morocco.—Compagnie de Tifnout Tighanimine (CTT) (a subsidiary of Groupe Managem) mined cobalt arsenide ores and produced crude cobalt hydroxide at Bou-Azzer. The hydroxide was refined to electrolytic cobalt (cobalt cathode) at CTT's Guemassa hydrometallurgical refinery north of Marrakech. CTT also refined cobalt from imported concentrate. In 2018, 68% of the cathode produced was from Bou-Azzer feed (70% in 2017). Refined cobalt production reportedly was below a target level of 2,000 t, owing to furnace problems. Increased exploration in 2018 led to the discovery of new ore reserves that will extend Bou-Azzer's mine life by 2 years. Managem was expanding its activity into other parts of Africa, including Congo (Kinshasa), where it completed a feasibility study on the Pumpi copper-cobalt project, which it was developing in partnership

with Wanbao Mining (Darton Commodities Ltd., 2019, p. 22, 41; Groupe Managem, 2019a, p. 15, 37, 39; 2019b, p. 14, 33).

New Caledonia.—In 2018, estimated recoverable mine production decreased by 24% compared with that in 2017 (table 7) because of a decrease in production from sole producer Vale Nouvelle-Calédonie S.A.S. (VNC) (Vale and Société de Participation Minière du Sud Caledonien S.A.S.). VNC continued to ramp up production at its operation in the southern tip of New Caledonia's main island, which consisted of a nickel-cobalt laterite mine, an HPAL processing plant, and a refinery. During the year, VNC added new trucks to its mining fleet, worked to update its mine plan, and evaluated ways to increase efficiency at the plant. Following rampup over the next 5 to 6 years, the operation was expected to have a nominal production capacity of 50,000 t/yr of nickel contained in nickel oxide and an estimated 4,000 t/yr of cobalt contained in an intermediate cobalt carbonate (Vale S.A., 2019, p. 11, 51).

Norway.—Glencore produced 4,200 t of electrolytic cobalt (cobalt cathode) at its Nikkelverk refinery, 20% more than the 3,500 t produced in 2017 (table 8). In 2018, the company's Sudbury and Raglan operations in Canada supplied 21% of the cobalt refined at Nikkelverk; the remaining feed was a mix of intermediate products and secondary (scrap) materials sourced from other companies, reportedly including an estimated 1,400 t of cobalt in intermediates from Nornickel (Darton Commodities Ltd., 2019, p. 15; 2020, p. 16; Glencore plc, 2019, p. 225).

Papua New Guinea.—In 2018, the Ramu nickel-cobalt joint venture operated by majority owner Metallurgical Corporation of China Ltd. (MCC) produced essentially the same amount of cobalt in intermediate nickel-cobalt hydroxide as it did in 2017 (table 7). The Kurumbukari nickel-cobalt laterite mine and Basamuk HPAL processing plant operated at close to the operation's design capacity of 3,300 t/yr of contained cobalt. During the year, MCC entered into a memorandum of investment agreement with the Ministry of Mines regarding an expansion of the operation's production capacity. The hydroxide was exported to China to be refined by Jinchuan and Jilin Jien Nickel Industry Ltd. (Darton Commodities Ltd., 2019, p. 32; Highlands Pacific Ltd., 2019, p. 4; Metallurgical Corporation of China, Ltd., 2019, p. 31).

Philippines.—Two HPAL 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 2018, production of intermediate nickel-cobalt sulfides from Coral Bay was higher than that in 2017; production from Taganito was lower than that in 2017 because of equipment problems at the plant, which had been expanded in 2017. Sumitomo worked to stabilize production at Taganito by improving preventative maintenance and spare parts management. The mixed sulfides were sent to Sumitomo's Niihama and Harima refineries in Japan (Darton Commodities Ltd., 2019, p. 17; Sumitomo Metal Mining Co., Ltd., 2019, p. 52, 63, 65–66).

Russia.—Production by Nornickel, the sole producer of refined cobalt in Russia, decreased for the second consecutive year (table 8). 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 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, Nornickel reportedly also produced about 1,100 t of cobalt in a cobalt intermediate in 2018, which was sent to be refined at Harjavalta and Glencore's Nikkelverk operation in Norway (Cobalt Institute, 2019; Darton Commodities Ltd., 2019, p. 20–21; PJSC MMC Norilsk Nickel, 2019, p. 72–73).

South Africa.—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Nornickel) produced 746 t of cobalt in nickel concentrate in calendar year 2018 (851 t in 2017). Concentrate from Nkomati was sold to Metal Trade Overseas AG (African Rainbow Minerals Ltd., 2018, p. 68; 2019, p. 58).

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 10% less than that in 2017, owing to lower receipts of converter matte. One of the company's two converter units was out of service for much of the year following a steam explosion in 2017 (Anglo American Platinum Ltd., 2019, p. 72–73). 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. Thakadu Battery Materials Pty. Ltd. was building a plant at Lonmin's base-metals refinery to refine Lonmin's crude sulfate to battery-grade nickel sulfate and byproduct cobalt hydroxide. For the 2 fiscal years ending June 30, 2018, and June 30, 2019, Northam reported sales of 10 t of cobalt in nickel sulfate from its base-metals recovery plant at Zondereinde (Creamer, 2018; Lonmin Plc, 2019, p. 21; Northam Platinum Ltd., 2019, p. 11, 41).

Turkey.—Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. (Vestel Elektronik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) produced intermediate nickel-cobalt hydroxide containing 5,001 t of nickel and 259 t of cobalt from its HPAL processing plant at Gordes, Manisa Province. The plant used local nickel-cobalt laterite ore as feed. Meta Nikel continued to ramp up production at the plant, worked to increase the plant's efficiency, worked on reserve development and ore production in Eskişehir Province, and planned investments to double plant capacity and produce value-added nickel sulfate and cobalt

sulfate products (Vestel Elektronik Sanayi ve Ticaret A.Ş., 2019, p. 67, 100–101).

Vietnam.—Asian Mineral Resources Ltd. sold its shares of AMR Nickel Ltd., majority owner of Ban Phuc Nickel Mines LLP, to Ta Khoa Mining Ltd. Prior to being placed on care-and-maintenance status in late 2016, the Ban Phuc mining operation sent the cobalt-bearing nickel-copper concentrate that it produced to Jinchuan for refining (Asian Mineral Resources Ltd., 2019, p. 2).

Zambia.—According to the Zambian Ministry of Mines and Mineral Development, production of mined cobalt decreased by 9% in 2018 from that in 2017 (table 7). Production of refined cobalt, which was mainly from imported concentrates, decreased by 36% from production in 2017 (table 8). Chambishi Metals (ERG and ZCCM Investments Holdings Plc) was the sole producer of refined cobalt in Zambia; the decrease in production of cobalt metal was attributed to declining cobalt grades in the ore mined by Boss Mining's operations in Congo (Kinshasa) (Darton Commodities Ltd., 2019, p. 19–20).

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, including companies with operations in Congo (Kinshasa). Darton Commodities Ltd. estimated that KCM's production of cobalt in alloy decreased by 22% to 700 t in 2018. 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 (Lewis, 2017; Fastmarkets MB Daily, 2018; Darton Commodities Ltd., 2019, p. 24).

CNMC mined and processed copper-cobalt ore in the Zambian Copperbelt through four majority-owned subsidiaries—NFC Africa Mining Plc (NFCA), Luanshya Copper Mines Plc, Chambishi Copper Smelter Ltd. (CCS), and Sino-Metal Leach Zambia Ltd. In 2018, CCS produced 1,136 t of copper-cobalt alloy containing 114 t of cobalt, compared with the 1,219 t of alloy containing 123 t of cobalt produced in 2017. Luanshya's Baluba Center copper-cobalt mine resumed production in July; the mine had been idled in late 2015 following a reduction in power supply. NFCA completed the main part of the integrated exploration and construction of its Chambishi Southeast Mine and started trial production in August. Once in commercial production, the Chambishi Southeast Mine was expected to produce about 1,000 t/yr of cobalt in concentrate (Luk, 2018; China Nonferrous Mining Corp. Ltd., 2019, p. 19, 32–33, 38, 179).

Mabiza Resources Ltd., a subsidiary of Consolidated Nickel Mines Ltd. (CNM) (United Kingdom), planned to restart production at the Munali nickel sulfide mine in southern Zambia in 2019. The mine has been on care-and-maintenance status since 2011. CNM took over as mine operator in 2014 and completely reassessed the project—reinterpreted the ore body, changed the mining method, revised the metallurgical process, and optimized the labor structure with the aim of reducing operating costs and making the mine economical at low nickel prices. The main product of the mine was to be nickel concentrate containing 5,000 t/yr of nickel, 200 t/yr of cobalt, plus copper and PGMs (Mfula, 2018; Pole, 2018).

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 2018 (Glencore plc, 2019, p. 225).

Zimbabwe.—The Mimosa platinum mine (Implats and Sibanye Gold Ltd.) produced cobalt in concentrate, which was refined by Implats in Springs, South Africa (Impala Platinum Holdings Ltd., 2018).

Zimplats Holdings Ltd. produced 79 t of cobalt from its PGM operations in calendar year 2018, similar to production in 2017. The company's project to refurbish its mothballed base-metals refinery at its Selous Metallurgical Complex in Mashonaland West Province remained on hold (Zimplats Holdings Ltd., 2019a, p. 31; 2019b, p. 3).

Bindura Nickel Corporation Ltd. (BNC) produced cobalt-containing concentrate from the Trojan nickel sulfide mine. During the year, BNC invested in a project to deepen the mine's shaft. The company's smelter restart project, which was 83% complete, remained on hold pending improvements in the nickel market (Bindura Nickel Corporation Ltd., 2019, p. 6–7, 38).

Outlook

Historically, trends in refined 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 11-year period between 2007 and 2017, cobalt consumption increased at a compound annual growth rate of 5.7%. This rate was forecast to increase to 9.5% between 2018 and 2025, driven mainly by cobalt's use in rechargeable lithium-ion batteries for electric vehicles (Darton Commodities Ltd., 2019, p. 71–72). 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.

The general consensus is that global cobalt supply is forecast to continue to increase. Cobalt mine and intermediate production could increase significantly in the near term, particularly from 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 cobalt content) began cobalt production in 2018. In 2019, Chemaf's Mutoshi operation (16,000 t/yr of cobalt content) and phase 1 of ERG's Metalkol RTR operation (14,000 t/yr of cobalt content) are scheduled to begin production. Production from these and other, smaller projects could provide enough cobalt raw materials to result in surplus cobalt supply in the near term. Beyond 2021, however, additional new supply is expected to be needed to meet the predicted increase in cobalt consumption for electric vehicles (Bedder, 2018, p. 10; Darton Commodities

Ltd., 2019, p. 29–30, 34, 40, 71–72; Heathman, 2019, p. 3, 8, 12; Katanga Mining Ltd., 2019, p. 14).

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TABLE 1
SALIENT COBALT STATISTICS[1]

(Metric tons, cobalt content, unless otherwise specified)

		2014	2015	2016	2017	2018
United States:						
Mine production[e]		120	760	690	640	490
Consumption:						
Reported		8,650	8,830	9,010	9,240	9,270
Apparent[2]		8,710	10,300	11,500	8,920 [r]	7,580
Imports for consumption		11,300	11,400	12,800	11,900	11,800
Exports		4,500	3,830	4,160	5,710 [r]	6,960
Stocks, December 31:						
Industry[3]		1,160	1,070	969	1,020	1,040
London Metal Exchange Ltd. (LME), U.S. warehouses		9	165	195	160	130
U.S. Government:[4]						
Metal		301	301	301	302	302
Lithium-cobalt oxide	gross weight	(5)	(5)	(5)	1	1
Lithium-nickel-cobalt-aluminum oxide	do.	(5)	1	1	2	2
Cobalt alloys	do.	--	--	--	(5)	3
Price, metal:						
U.S. spot[6]	dollars per pound	14.48	13.44	12.01	26.97	37.43
LME, cash[7]	do.	14.00	12.90	11.57	25.28	32.94
World:						
Production:						
Mine		115,000 [r]	122,000 [r]	112,000 [r]	125,000 [r]	148,000
Refinery		92,600	99,800	96,600	117,000	125,000
Stocks, December 31, LME[8]		489	630	691	580	863

[e]Estimated. [r]Revised. do. Ditto. -- Zero.
[1]Table includes data available through September 16, 2019. Data are rounded to no more than three significant digits, except prices.
[2]Defined as imports minus exports plus adjustments for Government and industry stock changes plus secondary production, as estimated from consumption of purchased scrap.
[3]Stocks held by cobalt processors and consumers.
[4]Source: Defense Logistics Agency Strategic Materials.
[5]Less than ½ unit.
[6]Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.
[7]Annual average mean of the cash buyer price and cash seller price, cobalt briquettes, cathode, ingot, or rounds, converted from dollars per metric ton. Effective January 19, 2018, the minimum grade of cobalt metal to be delivered under the cobalt contract was increased from 99.3% cobalt to 99.8% cobalt.
[8]Stocks held in Asia, Europe, and the United States.

TABLE 2
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT[1, 2]

(Metric tons, cobalt content)

	2017	2018
Consumption by end use:		
Steels and other alloys, excludes superalloys[3]	1,420	1,390
Superalloys	4,240	4,240
Cemented carbides[4]	753	797
Chemical and ceramic uses	2,830	2,840
Total	9,240	9,270
Consumption by form:		
Chemical compounds, organic and inorganic[5]	2,180	2,190
Metal	4,310	4,330
Purchased scrap	2,750	2,740
Total	9,240	9,270
Stocks, December 31:[6]		
Chemical compounds, organic and inorganic[5]	409	430
Metal	W	W
Purchased scrap	W	W
Total	1,020	1,040

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Table includes data available through July 24, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes estimates.
[3]Includes magnetic alloys, nonferrous alloys, welding materials, wear-resistant alloys, and other metallic uses not listed.
[4]Includes diamond tool matrices, cemented and sintered carbides, and cast carbide dies or parts.
[5]Includes oxides.
[6]Stocks held by cobalt processors and consumers.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM[1]

		2017			2018		
		Quantity (metric tons)		Value[4]	Quantity (metric tons)		Value[4]
Form	HTS[2] codes	Gross weight	Cobalt content[3]	(thousands)	Gross weight	Cobalt content[3]	(thousands)
Metal[5]	8105.20.6000, 8105.20.9000	9,530	9,530	$465,000	9,170	9,170	$621,000
Oxides and hydroxides	2822.00.0000	2,120	1,520	76,600	1,690	1,210	92,000
Other:							
Acetates	2915.29.3000	197	47	2,210	341	82	3,090
Carbonates	2836.99.1000	717	330	17,300	801	369	20,000
Chlorides	2827.39.6000	36	9	412	81	20	1,630
Sulfates	2833.29.1000	1,740	471	14,300	3,430	927	17,200
Total		14,300	11,900	576,000	15,500	11,800	755,000

[1]Table includes data available through July 24, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Estimated from gross weight using the following percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; carbonates, 46%; chlorides, 25%; and sulfates, 27%.
[4]Customs value.
[5]Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY OR LOCALITY[1]

	Metal[2]			Oxides and hydroxides[3]			Other forms[4]			Total		
	Quantity (metric tons)			Quantity (metric tons)			Quantity (metric tons)			Quantity (metric tons)		
Country or locality	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:												
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
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
2018:												
Australia	578	578	38,300	1	1	27	--	--	--	579	579	38,300
Belgium	36	36	3,320	628	452	35,500	29	8	143	693	496	39,000
Brazil	4	4	248	9	6	376	586	162	2,700	599	172	3,330
Canada	1,820	1,820	122,000	1	1	49	4	1	13	1,830	1,820	122,000
China	812	812	64,800	361	260	18,600	739	238	9,440	1,910	1,310	92,900
Finland	641	641	47,500	295	213	15,000	2,910	873	25,700	3,850	1,730	88,200
Germany	45	45	2,620	2	1	59	--	--	--	46	46	2,680
Hong Kong	46	46	3,760	--	--	--	--	--	--	46	46	3,760
Japan	1,760	1,760	125,000	(7)	(7)	3	--	--	--	1,760	1,760	125,000
Madagascar	798	798	65,200	--	--	--	--	--	--	798	798	65,200
Morocco	210	210	16,400	--	--	--	--	--	--	210	210	16,400
Norway	1,500	1,500	87,400	--	--	--	--	--	--	1,500	1,500	87,400
Russia	544	544	36,200	--	--	--	--	--	--	544	544	36,200
South Africa	287	287	4,260	--	--	--	11	5	382	298	292	4,640
Taiwan	--	--	--	30	22	1,210	--	--	--	30	22	1,210
United Kingdom	57	57	2,740	340	245	20,200	312	92	2,680	709	394	25,700
Other	29	29	1,700	19	14	864	63	19	954	111	61	3,520
Total	9,170	9,170	621,000	1,690	1,210	92,000	4,660	1,400	42,000	15,500	11,800	755,000

-- Zero.

[1]Table includes data available through July 24, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

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

[3]HTS code 2822.00.0000.

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

[5]Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; carbonates, 46%; chlorides, 25%; and sulfates, 27%.

[6]Customs value.

[7]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS OF COBALT, BY COUNTRY OR LOCALITY[1, 2]

	Metal[3]		Oxides and hydroxides[4]		Acetates[5]		Chlorides[6]		Total	
Country or locality	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)
2017	5,520 r	$116,000 r	200	$3,090	199	$2,420	6	$94	5,710 r	$122,000 r
2018:										
Argentina	20	1,210	--	--	--	--	--	--	20	1,210
Australia	44	2,440	--	--	--	--	--	--	44	2,440
Belgium	110	3,560	--	--	158	1,920	--	--	147	5,490
Brazil	149	7,180	9	550	--	--	--	--	156	7,730
Canada	3,190	25,000	32	770	--	--	--	--	3,210	25,800
Chile	4	150	--	--	--	--	--	--	4	150
China	59	3,410	3	104	--	--	--	--	61	3,510
Dominican Republic	4	22	--	--	--	--	--	--	4	22
Finland	23	2,610	--	--	--	--	--	--	23	2,610
France	759	21,300	(9)	15	--	--	--	--	759	21,300
Germany	229	16,700	2	77	--	--	--	--	230	16,800
Hong Kong	4	377	(9)	9	--	--	--	--	4	386
India	51	3,040	--	--	78	1,670	--	--	70	4,700
Indonesia	11	786	--	--	--	--	--	--	11	786
Ireland	836	27,900	--	--	--	--	--	--	836	27,900
Israel	5	280	--	--	--	--	--	--	5	280
Italy	25	867	(9)	3	--	--	--	--	25	870
Japan	138	8,560	(9)	4	--	--	--	--	138	8,560
Korea, Republic of	136	4,670	(9)	5	--	--	--	--	136	4,680
Malaysia	6	762	--	--	--	--	--	--	6	762
Mexico	9	807	21	1,220	42	873	1	20	34	2,920
Netherlands	212	14,500	--	--	--	--	--	--	212	14,500
Saudi Arabia	5	509	1	20	--	--	--	--	6	529
Singapore	85	4,520	(9)	3	--	--	--	--	85	4,520
South Africa	6	409	--	--	--	--	--	--	6	409
Taiwan	234	2,920	--	--	--	--	--	--	234	2,920
Turkey	25	1,240	--	--	--	--	--	--	25	1,240
United Arab Emirates	4	318	--	--	--	--	--	--	4	318
United Kingdom	420	12,500	(9)	20	--	--	(9)	6	420	12,500
Vietnam	32	2,450	--	--	--	--	--	--	32	2,450
Other	15	1,270	(9)	8	--	--	--	--	15	1,280
Total	6,850	172,000	69	2,810	278	4,460	1	25	6,960	180,000

rRevised. -- Zero.
[1]Table includes data available through July 24, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]In addition to the materials listed, the United States exported cobalt ores and concentrates and wrought cobalt and cobalt articles.
[3]Includes 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 8105.20.000 and 8105.30.0000.
[4]HTS code 2822.00.0000.
[5]HTS code 2915.29.3000.
[6]HTS code 2827.39.6000.
[7]Free alongside ship value.
[8]Estimated from gross weight using the following cobalt content percentages: metal, 100%; oxides and hydroxides, 72%; acetates, 24%; and chlorides, 25%.
[9]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6
WORLD ANNUAL COBALT REFINERY
CAPACITY, DECEMBER 31, 2018[1, 2]

(Metric tons, cobalt content)

Country or locality	Capacity
Australia	6,700
Belgium	3,000 [e]
Brazil	3,000 [e]
Canada[3]	8,020
China	102,000
Congo (Kinshasa)[4]	6,050 [e]
Finland	16,500
France	500
India	2,060 [e]
Japan	5,500 [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	187,000 [e]

[e]Estimated.

[1]Table includes data available through July 24, 2019. Data are rounded to no more than three significant digits; may not add to total shown.

[2]Includes standby capacity. Refinery products include cobalt metal, metal powders, oxides, and (or) salts.

[3]Revised downward to remove refining capacity at Vale S.A.'s Thompson, Manitoba, operation.

[4]Estimated capacity for La Générale des Carrières et des Mines SA's Shituru refinery was revised downward.

TABLE 7
COBALT: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, cobalt content)

Country or locality[3]	2014	2015	2016	2017	2018
Australia[4]	6,201	5,721	5,140	5,034	4,878
Botswana[5]	196	316	248	--	--
Brazil	3,828	2,771	200 e	-- e	-- e
Canada[6]	3,907	4,339	4,216 r	3,704 r	3,524
China[e]	2,800	2,600 r	2,300 r	2,500 r	2,000
Congo (Kinshasa)[e, 7]	65,000 r	72,000 r	68,000 r	80,000 r	104,000
Cuba[e, 8]	3,300 r	4,000 r	3,900 r	3,900 r	3,500
Finland[9]	770 e	440 e	690 e	1,000 e	1,377
Indonesia[e, 10]	1,300	1,300	1,200	1,200	1,200
Madagascar[e, 11]	3,400	4,000	3,800	3,600 r	3,300
Mexico[e]	--	--	980	1,000	1,400
Morocco[e, 12]	1,400 r	1,500 r	1,600 r	2,300 r	2,100
New Caledonia[e, 13]	4,040	3,640	3,390	2,780	2,100
Papua New Guinea[14]	2,134	2,505	2,191	3,308	3,275
Philippines[e, 15]	4,600	4,300	4,000 r	4,600	4,600
Russia[e, 16]	6,300	6,200	5,500	5,900	6,100
South Africa[e]	3,000	2,900	2,300	2,300	2,300
Turkey[14]	--	NA	100 e	220	259
United States[e, 16]	120	760	690	640	490
Vietnam[16]	223	277	134	--	--
Zambia	2,300 e	1,700 e	600 e	990 r	897
Zimbabwe[17]	358	355	409	445	403
Total	115,000 r	122,000 r	112,000 r	125,000 r	148,000

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]Table includes data available through September 16, 2019. 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.

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

[3]In addition to the countries and (or) localities 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.

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

[5]Reported cobalt content of pelletized nickel-copper matte.

[6]Recoverable cobalt in ores and concentrates shipped.

[7]Determined from reported or estimated cobalt content of materials originating from mining and processing operations in Congo (Kinshasa) such as ores, concentrates, refined cobalt metal, and intermediate products including crude cobalt alloys, crude cobalt hydroxide, and crude cobalt carbonate produced from cobalt ores and concentrates, tailings, or slags.

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

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

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

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

[12]Cobalt content of concentrate estimated from reported gross weight.

[13]Cobalt 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.

[14]Cobalt content of nickel-cobalt hydroxide.

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

[16]Cobalt content of concentrates.

[17]Production reported by the Zimbabwe National Statistics Agency.

TABLE 8

COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, cobalt content)

Country or locality and form	2014	2015	2016	2017	2018
Australia, metal powder and oxide hydroxide[3]	5,419	5,150	3,350 [e, 4]	3,000	3,200
Belgium, metal powder, oxide, hydroxide[e, 5]	1,300	1,500	1,500	1,600	1,650
Brazil, metal[3]	1,350 [6]	1,300	400	46	8
Canada, metal, metal powder, oxide	5,491	6,126	6,302	6,355	6,300 [e]
China, metal, metal powder, oxide, salts[e]	43,800	53,500	49,900	75,000	83,100
Congo (Kinshasa), metal[7]	2,859	3,141	50	120	60
Finland, metal powder and salts[8]	12,551	9,615	12,393	12,222	12,874
France, chloride[3]	219	133	119	277	48
India, metal and salts[3]	100	150	100	100	100
Japan, metal[3]	3,654	4,259	4,305	4,159	3,669
Madagascar, metal powder	2,915	3,464	3,273	3,053	2,852
Mexico, metal	--	--	419	420 [e]	226
Morocco, metal	1,391	1,982	2,081	1,924	1,806
Norway, metal[9]	3,600	3,100	3,500	3,500	4,200
Russia, metal[3]	2,302	2,040	3,092	2,077	1,800
South Africa, metal powder and sulfate[3]	1,332 [10]	1,300	1,101	1,062	1,089
Zambia, metal[3]	4,317	2,997	4,725	2,520	1,613
Total	92,600	99,800	96,600	117,000	125,000

[e]Estimated. -- Zero.

[1]Table includes data available through August 19, 2019. 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.

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

[3]Production reported by the Cobalt Institute (formerly Cobalt Development Institute), except as noted.

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

[5]Production estimate reported by Darton Commodities Ltd.

[6]Production reported by National Department of Mineral Production.

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

[8]Production reported by the Geological Survey of Finland.

[9]Production reported by Glencore plc.

[10]Production reported by the Department of Mineral Resources.