



2012 Minerals Yearbook

COBALT [ADVANCE RELEASE]

COBALT

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In 2012, world production of refined cobalt decreased for the first time since 2007, mainly the result of decreased production in China. The United States did not refine cobalt in 2012. A negligible amount of byproduct cobalt was produced domestically in an intermediate product from the mining and refining of platinum-group metals (PGM) ore. No cobalt has been sold from the National Defense Stockpile (NDS) since 2009.

According to the Cobalt Development Institute (2013a), world apparent consumption of cobalt decreased by about 6% to approximately 72,000 metric tons (t) from that of 2011. Based on the Institute's statistics, apparent consumption in all geographic areas was lower than that in 2011. Cobalt prices trended downward in 2012. Salient U.S. and world cobalt statistics for 2008–12 are listed in table 1.

Cobalt is a metal used in numerous diverse commercial, industrial, and military applications. On a global basis, 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 2012. Sales of cobalt were curtailed in early 2008 in order to hold an inventory goal quantity equivalent to 1 year's Annual Materials Plan (AMP) amount. The AMP amount for fiscal year 2012 (October 1, 2011, through September 30, 2012) was 301 t (663,709 pounds), which was equal to the total uncommitted cobalt inventory held by DLA Strategic Materials since March 31, 2010. The 2011 Biennial Report on Stockpile Requirements listed cobalt metal as a material that was not required in the NDS (U.S. Department of Defense, 2009, p. 1–2; 2013, p. 4, 7–8).

In 2012, as part of its proposed AMP for fiscal year 2014, the NDS Market Impact Committee included the potential acquisition of 750 kilograms (kg) of lithium cobalt oxide and 540 kg of lithium nickel cobalt aluminum oxide. These materials are used to make rechargeable batteries (U.S. Department of Commerce, 2012).

Production

With the exception of negligible amounts of byproduct cobalt produced from Stillwater Mining Co.'s PGM operations in southeastern Montana, the United States did not mine or refine cobalt in 2012. Stillwater produced cobalt-bearing nickel sulfate from its mining and refining operations, which it sold to other companies (Stillwater Mining Co., undated).

Formation Metals Inc. completed stage II construction (mine site preparation) on its Idaho Cobalt Project, which would entail an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County and a retrofitted Big Creek hydrometallurgical complex near Kellogg, ID, to refine the concentrates. Formation planned to begin stage III construction (underground mine development, mill construction, and retrofitting the hydrometallurgical plant) after additional project finance was secured, and expected that initial production would begin 9 to 14 months after commencing underground development (table 7) (Formation Metals Inc., 2013, p. 9–10).

Kennecott Minerals Co., a fully owned subsidiary of Rio Tinto (Melbourne, Australia, and London, United Kingdom), reportedly completed 80% of the construction on its small nickel-copper mine in the Eagle deposit northwest of Marquette, MI. The full project, including the rehabilitated mill in Humboldt Township, was approximately one-half completed. Production startup was delayed until the second half of 2014, reportedly owing to unfavorable economic conditions (table 7) (Pepin, 2013).

The Minnesota Department of Natural Resources, U.S. Army Corps of Engineers, and U.S. Forest Service continued to work on preparing a supplemental draft environmental impact statement for PolyMet Mining Corp.'s NorthMet project. The project entailed open pit mining of the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota, refurbishing the crushing and grinding equipment in the company's nearby Erie plant, and adding a new beneficiation circuit and hydrometallurgical plant (table 7). PolyMet and Swiss trading firm Glencore International AG had a strategic partnership whereby Glencore was investing in PolyMet and would purchase or market NorthMet's products (PolyMet Mining Corp., 2013, p. 15, 29).

U.S. processors made cobalt chemicals and cobalt metal powder 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. The sole producer of cobalt metal powder, Global Tungsten & Powders Corp. of Towanda, PA, produced the cobalt powder as a byproduct of tungsten recovery from cemented carbide scrap. U.S. production

and shipments of cobalt metal powder were withheld to avoid disclosing company proprietary data.

Consumption

U.S. reported consumption of cobalt in 2012 was 7% less than that of 2011. Metallurgical industries used 10% less cobalt than they did in 2011, and cobalt consumption for chemical uses decreased slightly. Reported consumption was derived by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses 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 60 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 2012, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 3% higher than that in 2011 (table 1). The increase was caused by an increase in net imports in 2012 compared with those in 2011 and a drawdown in industry stocks. The discrepancy between the trend in reported consumption (a decrease from that of 2011) and the trend in apparent consumption (an increase from that of 2011) may have been the result of changes in unreported stock levels.

Prices

The annual average U.S. spot price for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, was 22% lower than that of 2011 (table 1). Although the price fluctuated during the year, the overall trend was downward. The highest price range was \$16.00 to \$16.90 per pound in late February through mid-March, and the lowest price range was \$10.80 to \$11.80 per pound in December.

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 \$13.30 per pound, and the annual average of weekly prices for Russian cobalt was \$13.49 per pound.

In 2012, cobalt from Ganzhou Yi Hao Umicore Industries Co. Ltd. (Ganzhou, China) was approved for delivery on the London Metal Exchange (LME) cobalt futures contract, bringing the total number of cobalt producers accepted by the LME to 14. The annual average means of cash buyer and cash seller and settlement prices and yearend LME inventory levels are listed in table 1 (London Metal Exchange Ltd., The, undated).

China's FANYA Metal Exchange began trading cobalt. FANYA listed electrolytic cobalt with a minimum delivery of 250 kilograms (Yang, 2012).

Foreign Trade

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was 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 2012, net import reliance as a percentage of apparent consumption was 77%. Because there was no measurable U.S. primary cobalt production in 2012, this indicates that 77% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 23% was from domestic or imported scrap.

In 2012, the United States imported 4% more cobalt than it did in 2011 (tables 3, 4). On the basis of cobalt content, ten countries supplied 87% of U.S. imports. China was the leading supplier, followed by Finland, Norway, Zambia, Russia, Canada, Australia, Japan, Brazil, and Belgium.

The United States imported 856 t, gross weight, of unwrought cobalt alloys valued at \$27.6 million. Most of these materials were from Canada (76%) and the United Kingdom (15%). The United States imported 820 t, gross weight, of cobalt waste and scrap valued at \$12.8 million. Seven countries supplied nearly 90% of this material—Ireland (26%), the United Kingdom (25%), Germany (10%), France (9%), Japan (8%), Canada (7%), and Belgium (4%). The United States also imported 279 t, gross weight, of wrought cobalt and cobalt articles valued at \$28.4 million. The leading suppliers of these materials were the United Kingdom (29%), Canada and China (17% each), Germany (14%), and France (12%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased 11% by volume compared with those of 2011. As listed in table 5, on the basis of cobalt content, the leading destinations for these exports were France, Ireland, the United Kingdom, Canada, Japan, China, and Germany. The United States also exported 1,820 t, gross weight, of wrought metal and cobalt articles valued at \$106 million.

World Review

World cobalt mine and refinery production decreased in 2012 compared with production in 2011, mainly owing to a decrease in estimated refinery production in China and a coincident reduction in China's imports of cobalt ores and concentrates from Congo (Kinshasa). 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 2012. Expansions to those operations, operation restarts, and greenfield projects that were forecast to begin producing between 2013 and 2017 are listed in table 7.

Australia.—In 2012, Western Australian cobalt mine production increased by more than 50% to 5,882 t from that in 2011 (table 8). Some of the increase can be attributed to

increases in production from First Quantum Minerals Ltd. and Minara Resources Ltd.; in addition, Queensland Nickel Pty Ltd. began production from the Brolga Mine.

Minara Resources (100% owned by Glencore) produced 2,490 t of cobalt as metal powder and briquettes from the Murrin Murrin nickel-cobalt laterite mining and pressure-acid leaching operation near Leonora, Western Australia. This was an increase of 19% from the 2,091 t produced in 2011. In 2012, 96% of the feed was from Minara's own operations and 4% was ore from third party sources (Glencore International plc, 2013, p. 51).

First Quantum ramped up production from its Ravensthorpe nickel-cobalt laterite mine and hydrometallurgical processing plant. In 2012, the plant produced mixed nickel-cobalt hydroxide containing 32,884 t of nickel and, based on the mixed hydroxide containing 40% nickel and 1.4% cobalt, an estimated 1,100 t of cobalt (5,666 t nickel and an estimated 200 t cobalt in 2011) (First Quantum Minerals Ltd., 2013, p. 28, 31).

The Palmer Nickel and Cobalt Refinery (owned by Australian businessman Clive Palmer, operated by Queensland Nickel, and formerly named Yabulu) in Townsville, Queensland, produced 2,369 t of refined cobalt as cobalt oxide hydroxide; 10% less than the 2,631 t produced in 2011. The refinery processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines, and an intermediate cobalt compound from Vale S.A.'s New Caledonia operation. Late in the year, Queensland Nickel announced that it had received approval to mine nickel laterite ore from Brolga in central Queensland and planned to make the first delivery of ore from Brolga to the refinery by yearend (Queensland Nickel Pty Ltd., 2012; Cobalt Development Institute, 2013a; Darton Commodities Ltd., 2013, p. 16).

BHP Billiton'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 mixed sulfide. Darton Commodities Ltd. estimated that BHP Billiton shipped 665 t of cobalt contained in mixed sulfide from Kwinana to Jinchuan Group Ltd. for refining in 2012 (475 t in 2011) (Darton Commodities Ltd., 2013, p. 18).

OJSC MMC Norilsk Nickel increased production from the Maggie Hays nickel sulfide mine and Lake Johnston mill in Western Australia. Nickel concentrates from the mill were processed by third party companies (OJSC MMC Norilsk Nickel, 2013b).

Panoramic Resources Ltd. produced concentrates containing 401 t of cobalt (453 t in 2011) from its Savannah underground nickel-copper sulfide mine operation in Western Australia. The concentrates were shipped to Jinchuan's operations in China under a long-term offtake agreement (Panoramic Resources Ltd., 2012, p. 5; 2013, p. 6).

Xstrata Nickel Australasia produced 322 t of cobalt in nickel sulfide concentrates from the Cosmos and Sinclair operations in Western Australia, compared with 396 t in 2011. The Cosmos Mine was placed on care-and-maintenance status in late 2012 in response to a prolonged period of low nickel prices and a strong Australian dollar (Xstrata plc, 2013, p. 8–9).

Belgium.—According to the Cobalt Development Institute (2013a), Umicore's 2012 cobalt refinery production increased by 32% to 4,200 t of contained cobalt from 3,187 t produced in 2011. Umicore converted various cobalt materials into a wide range of chemicals and metal powders. The company's cobalt refining took place at plants in Olen, Belgium, and Ganzhou, China. Umicore also had cobalt processing plants, which made specialty products from refined cobalt or scrap, in Arab, AL, the United States; Bruges, Belgium; Fort Saskatchewan, Alberta, Canada; Jiangmen and Shanghai, China; and Cheonan, Republic of Korea. In 2012, Umicore processed record volumes of material at its recycling and refining facilities and announced several investments—it planned to increase production capacity of fine cobalt powders in Olen and to expand production of battery materials in the Republic of Korea and China (n.v. Umicore, s.a., 2013, p. 48–49).

Botswana.—Tati Nickel Mining Co. Pty. Ltd. (a Norilsk subsidiary) mined the Phoenix open pit and produced nickel-copper sulfide concentrates, which were toll-smelted by BCL Ltd. in Botswana. BCL also smelted concentrate from its Selebi-Phikwe operation in Botswana. Matte produced by BCL was refined by RioZim Ltd. in Zimbabwe and Xstrata Nickel in Norway.

Brazil.—Votorantim Metais SA planned to increase the cobalt production capacity at its Sao Miguel Paulista, Sao Paulo State, refinery to 3,000 metric tons per year (t/yr). Feed for the refinery was lateritic nickel-cobalt ore mined from Niquelandia, Goias State, and nickel sulfide concentrate from Mirabela Nickel Ltd. Votorantim also produced nickel matte, primarily from sulfide ores mined and smelted at Fortaleza de Minas, Minas Gerais State (Votorantim Metais SA, 2011).

Mirabela Nickel continued to ramp up production from its Santa Rita open pit nickel sulfide mine and concentrator in Bahia State, and produced 335 t of cobalt in concentrate (273 t in 2011). All concentrate produced at Santa Rita was committed through offtake agreements to Votorantim (50%) and Norilsk (50%) (Mirabela Nickel Ltd., 2013).

Canada.—Vale produced 2,343 t of cobalt in 2012, 12% less than the 2,675 t produced in 2011. Vale reported producing 1,284 t of refined cobalt metal at its Port Colborne, Ontario, refinery; 606 t of cobalt in an intermediate product at its Thompson, Manitoba, refinery; and 452 t of cobalt contained in other intermediate products, including nickel concentrates, from its New Caledonian operation and from external sources. Vale's cobalt came from company-owned nickel sulfide mines at Sudbury, Ontario, at Thompson, Manitoba, and at Voisey's Bay in northeastern Labrador; from a company-owned nickel laterite mine in New Caledonia; and from purchased feedstocks. Vale reported that 589 t (593 t in 2011) of cobalt came from Ontario, 96 t (158 t in 2011) came from Manitoba, 1,221 t (1,585 t in 2011) came from Voisey's Bay, 385 t (245 t in 2011) came from New Caledonia, and 52 t (93 t in 2011) came from external sources. Concentrates from Voisey's Bay were being smelted and refined at Sudbury and Thompson until the Long-Harbour refinery becomes operational (table 7). Vale planned to phase out smelting and refining at Thompson at the end of 2015 (Winnipeg Free Press, 2012; Vale S.A., 2013, p. 37–38, 48).

Xstrata Nickel produced 563 t of cobalt in concentrates from mines at Sudbury (473 t in 2011) and 602 t of cobalt in concentrate from its Raglan Mine in Quebec (562 t in 2011). The company produced nickel-copper matte containing 2,193 t of cobalt at its Sudbury smelter (2,209 t in 2011); this was refined at Xstrata's Nikkelverk refinery in Norway. Some of the cobalt in the matte originated from ores produced at company mines in Australia and Canada and some originated from custom feed materials, which were primarily nickel concentrates and nickel-copper-cobalt scrap (Xstrata plc, 2013, p. 8–9).

The Fort Saskatchewan refinery, a joint venture of Sherritt International Corp. and General Nickel Co. S.A., produced 3,792 t of cobalt as metal powder and briquettes in 2012, slightly less than the 3,854 t produced in 2011. Approximately 98% of the cobalt was from nickel-cobalt mixed sulfides from the joint venture's operations at Moa Bay, 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 cannot be sold to customers in the United States (Sherritt International Corp., 2013a, p. 7, 13, 95–97).

China.—China was the world's leading producer and consumer of refined cobalt. In 2012, China's refinery production decreased compared with that of 2011 and its consumption increased by 8.5% to 31,700 t. Two-thirds of the consumption was used to make cathode materials for rechargeable batteries (Wu, 2013, p. 16).

Only a small portion of China's cobalt originated from domestic mines and recycled scrap. Most was from imported ores, concentrates, and semirefined materials, the majority of which was sourced from Congo (Kinshasa). CRU International Ltd. (2013, p. 7) estimated that China imported 29,000 t of cobalt contained in ores, concentrates, and semirefined materials in 2012, 15% less than the 34,100 t imported in 2011. China imported significantly less cobalt in ores and concentrates (9,540 t in 2012 compared with 18,800 t in 2011) and more cobalt in semirefined materials (19,400 t in 2012 compared with 15,300 t in 2011). The decreases in total imports and refinery production in 2012 were attributed to a surplus of raw materials and refined cobalt, which accumulated during 2009–11. Analysts estimated that these stocks decreased by 6,000 to 9,000 t of cobalt during 2012 from an estimated 25,000 t of cobalt held at yearend 2011 (Darton Commodities Ltd., 2013, p. 19–20).

Numerous companies refined and (or) processed cobalt in China. Jinchuan and Zhejiang Galico Cobalt & Nickel Material Co., Ltd. were the leading refiners, based on 2012 estimated cobalt production. Jinchuan produced cobalt as cathode and other products at its refinery in Jinchang, Gansu Province. Some of Jinchuan's cobalt production was from domestic nickel-copper-cobalt sulfide ores mined at Jinchang and some was from other cobalt or nickel feeds. These other feeds included cobalt intermediates (chemical compounds) from Congo (Kinshasa) and Zambia; nickel-cobalt hydroxide from Papua New Guinea; nickel and nickel-copper concentrates from Australia, Finland, and Spain; and nickel matte and mixed sulfides from BHP Billiton (CRU International Ltd., 2013, p. 4, 6; Darton Commodities Ltd., 2013, p. 10, 16, 18).

Congo (Kinshasa).—Congo (Kinshasa) was the world's leading producer of mined cobalt. Some of the country's cobalt mine production was from copper-cobalt ores mined by traditional methods, and some was gathered by tens of thousands of artisanal miners by hand-picking cobalt-rich ores. Some of Congo (Kinshasa)'s ores and concentrates were exported, some were processed to semirefined materials such as cobalt carbonate, cobalt hydroxide, or cobalt-bearing alloys, and some were refined to cobalt metal. China was the leading destination for Congo (Kinshasa)'s cobalt exports. As discussed in the "China" section of this report, exports of cobalt materials to China decreased in 2012 compared with those of 2011.

La Générale des Carrières et des Mines (Gécamines) produced 870 t of refined cobalt, compared with 650 t produced in 2011. In 2012, Gécamines purchased the 60% share in Compagnie Minière du Sud Katanga (CMSK) held by L'Entreprise Générale Malta Forrest S.P.R.L. This gave Gécamines full ownership of CMSK and was part of Gécamines' plan to convert itself into a leading independent mining company. CMSK produced copper-cobalt concentrate from the Luiswishi Mine and Kipushi concentrator (L'Entreprise Générale Malta Forrest S.P.R.L. and La Générale des Carrières et des Mines, 2012; Cobalt Development Institute, 2013a).

Kamoto Copper Company SARL (KCC) (Katanga Mining Ltd., Gécamines, and La Société Immobilière du Congo) produced 2,129 t of cobalt cathode in 2012, compared with 2,433 t in 2011. The decrease was attributed to recurrent general power disruptions, various mechanical issues, and mining ore with a lower cobalt grade. The company's Luilu refinery processed concentrates produced at its Kamoto concentrator from ore extracted from its Kamoto underground mine and KOV open pit. At yearend, KCC was commissioning the phase 4 expansion of its operations (table 7). Glencore had offtake agreements for all of KCC's copper and cobalt output; the company also sold copper concentrates to Mopani Copper Mines and Sable Zinc Kabwe Ltd. in Zambia (Katanga Mining Ltd., 2013, p. 6–10, 28–29).

Boss Mining Sprl [70% Eurasian Natural Resources Corp. PLC (ENRC) and 30% Gécamines] mined copper-cobalt ore from the Mukondo Mountain and Chimbedia open pits. During the year, Boss Mining extracted 22% more cobalt ore than it did in 2011, but production of saleable cobalt decreased, owing to lower recovery rates caused by changes in mineralogy and decreased availability of oxide ore.

In March, ENRC acquired certain assets from First Quantum, including the Kolwezi Processing Facility. At yearend, ENRC completed an acquisition of Camrose Resources Ltd. and gained a 70% interest in Treatment of Kingamyambo Tailings Co. (Metalkol), owner of the mineral license for the tailings to be processed by the Kolwezi Processing Facility. The Kolwezi project was renamed Roan Tailings Reclamation project (table 7) (Eurasian Natural Resources Corp. PLC, 2013, p. 37, 120, 122).

The Big Hill smelter at Lubumbashi [operated as a joint venture between Gécamines, OM Group, Inc. (OMG), and S.A. Groupe George Forrest] processed stockpiled slag to produce alliage blanc, an alloy of cobalt and copper, which was refined at

OMG's Kokkola refinery. In 2012, the smelter's production was reduced by electrical problems in Congo (Kinshasa). At yearend, OMG was negotiating for the sale of its cobalt assets, including Big Hill (OM Group, Inc., 2013a, p. 19; 2013b).

Freeport-McMoRan Copper & Gold Inc. (FCX) produced 11,669 t of cobalt in hydroxide from its Tenke Fungurume mining and processing operation, compared with 11,182 t in 2011. The cobalt hydroxide reportedly was sent to refining operations in Belgium, China, Finland, and Zambia. At yearend, the phase 2 expansion of the project was substantially complete, and FCX forecast that it would sell 13,600 t of cobalt in 2013 (table 7) (Lundin Mining Corp., 2013, p. 5, 23–24; Darton Commodities Ltd., 2013, p. 9).

Mutanda Mining SPRL (Glencore International AG, High Grade Minerals S.A., and Rowny Assets Ltd.) completed the phase 2 and phase 3 expansions of its copper-cobalt hydrometallurgical plant, bringing the production capacity to 23,000 t/yr of cobalt in hydroxide. In 2012, Mutanda mined copper-cobalt oxide ore from open pits near Kolwezi and produced 8,500 t of cobalt in concentrate and hydroxide, 8% more than the 7,870 t produced in 2011 (Glencore International plc, 2013, p. 51–52).

Chemaf SPRL mined copper-cobalt oxide ores from the Etoile open pit mine, and processed run-of-mine ore, concentrates, and ore purchased from third parties at its solvent extraction-electrowinning (SX-EW) plant at Usoke in Lubumbashi. Chemaf planned to build a second refinery (table 7), which would increase its production capacity to 6,000 t/yr of cobalt in hydroxide or carbonate. The company also operated a pilot cobalt electrowinning plant, which had the capacity to produce 50 t/yr of cobalt (Shalina Resources Ltd., undated a, b).

Metorex Ltd.'s Ruashi operation north of Lubumbashi comprised copper-cobalt oxide open pits, a mill, and an SX-EW refinery, where cobalt carbonate or hydroxide were produced. Gécamines had a 25% interest in the Ruashi operation. In early 2012, Jinchuan completed a takeover of Metorex (Metorex Ltd., 2012, p. 3, 22–23).

Société Minière du Katanga sprl (Somika) mined and beneficiated copper-cobalt ore, and refined the concentrate at its hydrometallurgical copper refinery in Lubumbashi. The refinery had the capacity to produce 2,160 t/yr of cobalt hydroxide (Société Minière du Katanga sprl, undated).

African Metals Corp. completed construction of its dense media separation plant and began processing stockpiled ore from its Luisha South project. The project was expected to produce copper concentrates containing approximately 200 t/yr of cobalt (African Metals Corp., 2012).

Cuba.—Moa Nickel S.A. (part of the 50-50 joint venture between Sherritt and General Nickel) mined nickel-cobalt laterites at Moa Bay, Holguin Province, and produced mixed sulfides, which were sent to the joint venture's Fort Saskatchewan refinery in Canada. In 2012, the mixed sulfides contained 38,054 t of nickel and cobalt, slightly less than the 38,641 t produced in 2011 (Sherritt International Corp., 2013a, p. 12).

Grupo Empresarial Cubaníquel S.A.'s Ernesto Che Guevara and Rene Ramos Latour Mining and Metallurgical Combines

also mined and processed nickel-cobalt laterites in Holguin Province. Nickel and cobalt originating in Cuba cannot be imported into the United States because of a United States embargo on imports from Cuba (Sherritt International Corp., 2013a, p. 95–97).

Finland.—OMG produced refined cobalt, as metal powders, briquettes, oxides, and compounds. The company's Kokkola Chemicals Oy refinery processed raw materials sourced primarily from Congo (Kinshasa), Finland, and Russia. Most of the feed was alliage blanc from the Big Hill smelter in Congo (Kinshasa), crude cobalt hydroxide from Norilsk's Monchegorsk nickel refinery in Russia, and cobalt sulfate solution from Norilsk's Harjavalta nickel refinery in Finland. In 2012, the 5-year cobalt supply agreement between Norilsk and OMG expired and was reportedly replaced by an annual agreement that would expire in June 2013. At yearend, OMG was negotiating the sale of its cobalt assets, including the Kokkola refinery (OM Group, Inc., 2013a, p. 5; 2013b; Darton Commodities Ltd., 2013, p. 12).

Norilsk's Harjavalta refinery processed nickel concentrates from the company's Nkomati operation in South Africa, from Mirabela Nickel in Brazil, and from Vale's Voisey's Bay operation; nickel-cobalt sulfide from Talvivaara Mining Co. Plc's operation in Finland; and nickel matte from Votorantim's Fortaleza smelter in Brazil and BHP Billiton's Kalgoorlie smelter in Australia (OJSC MMC Norilsk Nickel, 2013a, p. 66; 2013b).

Talvivaara Mining Co. Plc's production from its polymetallic sulfide mine and bioheap-leaching operation in Sotkamo in central Finland was less than that of 2011. The decrease was attributed to two temporary suspensions of operations at the metal recovery plant and rapid snow melt and historically heavy rainfall that diluted the metal grades of the bioleach solution. In 2012, Talvivaara sold nickel-cobalt sulfide containing approximately 355 t of cobalt to Norilsk for processing at Harjavalta (Talvivaara Mining Co. Plc, 2013, p. 71–72, 94).

Belvedere Resources Ltd. produced an estimated 90 t of cobalt in nickel-copper concentrates from the Hitura Mine. The concentrates were sold to Jinchuan (Belvedere Resources Ltd., 2013, p. 2, 12).

Altona Mining Ltd. began production at its Outokumpu copper project, which comprised the Kylylahti underground polymetallic base metal sulfide mine and refurbished Luikonlahti beneficiation plant. At full production, Altona expected to produce approximately 80,000 t/yr of cobalt-nickel concentrate, containing an average of 940 t/yr of cobalt, which was to be stockpiled until a marketable product was developed (Altona Mining Ltd., undated).

First Quantum Minerals Ltd. completed construction of its Kevitsa open pit nickel-copper-PGM sulfide mine and beneficiation plant and began commercial production. The plant produced separate nickel and copper concentrates; the nickel concentrate contained an estimated 185 t of cobalt (First Quantum Minerals Ltd., 2013, p. 8, 36).

France.—The Eramet Group's production of cobalt chloride from its refinery at Sandouville was 8% less than that produced in 2011. Feed for the refinery was nickel matte imported from

Eramet subsidiary Société Le Nickel's Doniambo smelter in New Caledonia (Cobalt Development Institute, 2013a).

India.—According to an estimate by the Cobalt Development Institute (2013a), India's cobalt production decreased by 38% from that of 2011. Nicomet Industries Ltd. and Rubamin Ltd. were India's leading cobalt producers, but Rubamin reportedly ceased production in mid-2012 when restrictions on its plant's water discharge led to reduced production and profitability (Ryan's Notes, 2012).

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 (80%) and Sumitomo Metal Mining Co., Ltd. (20%) under long-term contracts.

PT Antam Tbk exported lateritic nickel-cobalt ore to the Palmer Nickel and Cobalt Refinery in Queensland for processing (CRU International Ltd., 2013, p. 4).

Japan.—Sumitomo's production of electrolytic cobalt at its Niihama nickel refinery increased by 27% from that of 2011. The refinery processed nickel-cobalt mixed sulfide feed from the Coral Bay Nickel Corp. plant in the Philippines and nickel matte from PT Inco in Indonesia and BHP Billiton's Nickel West operations. Sumitomo was increasing Niihama's production capacity to accommodate the nickel-cobalt mixed sulfide feed that would be generated from its Taganito project in the Philippines (table 7) (Cobalt Development Institute, 2013a).

Madagascar.—Sherritt completed construction and commissioning of the Ambatovy project, which comprised mining nickel-cobalt laterite ore in eastern central Madagascar and transporting slurried ore by pipeline to a processing plant and refinery located near the Port of Toamasina. By yearend, Ambatovy had produced 8,972 t of nickel and cobalt in mixed sulfide, 5,695 t of nickel metal, and 493 t of cobalt metal. Sherritt's partners in the project were Sumitomo Corp., Korea Resources Corp., and SNC-Lavalin Group Inc. (Sherritt International Corp., 2013b, p. 34).

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. The decrease in CTT's refined cobalt production in 2012 was attributed to disruption by social movements at Bou-azzer (Groupe Managem, 2013, p. 24, 27).

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 2012, Vale produced 385 t of cobalt from New Caledonia (245 t in 2011). Following ramp-up, Vale New Caledonia was expected to have a nominal production capacity of 60,000 t/yr of nickel contained in nickel oxide and 4,600 t/yr of cobalt contained in an intermediate cobalt carbonate (Vale S.A., 2013, p. 39, 48).

Lateritic nickel-cobalt ore was exported to the Palmer Nickel and Cobalt Refinery in Queensland 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.

Norway.—Xstrata Nickel's production of cobalt cathode at its Nikkelverk refinery was 3% less than that of 2011. The cobalt originated from matte produced at Xstrata's Sudbury smelter in Canada and custom feed, which included matte from Botswana processed under a long-term agreement with BCL. Glencore was the sole distributor of Xstrata's cobalt (CRU International Ltd., 2013, p. 4).

Papua New Guinea.—In early 2012, the Ramu Nickel joint venture (operated by majority owner Metallurgical Corporation of China Ltd.) began commissioning its nickel-cobalt laterite mine, beneficiation plant, and high-pressure acid-leach processing plant. By yearend, the operation had generated approximately 469 t of cobalt in intermediate nickel-cobalt hydroxide. Ramp up to full production was expected during 2013. Ramu was designed to produce 3,300 t/yr of cobalt (Highlands Pacific Ltd., 2013, p. 16–19).

Philippines.—Coral Bay Nickel (a joint venture between Sumitomo, Mitsui & Co., Ltd., Sojitz Corp., and Rio Tuba Nickel Mining Corp., listed in order of share) produced nickel-cobalt mixed sulfide from its high-pressure acid-leaching operation at the Rio Tuba nickel laterite mine on Palawan Island. The mixed sulfide was refined by Sumitomo in Japan.

Russia.—Norilsk conducted nickel-copper sulfide mining, ore beneficiation, concentrate smelting, and metal refining on the Taimyr and Kola Peninsulas. Cobalt from ores mined on the Taimyr Peninsula was refined to metal ingot and oxide at the company's nickel plant at Norilsk. According to the Cobalt Development Institute (2013a), the company produced 2,186 t of refined cobalt, 6% less than the 2,337 t produced in 2011. At Norilsk's nickel refinery at Monchegorsk on the Kola Peninsula, cobalt-bearing nickel materials from Kola and elsewhere were refined. The intermediate cobalt hydroxide product was sent to OMG's operations in Finland under a 5-year supply agreement that began in 2007. Under this agreement, Norilsk was to supply OMG with up to 2,500 t/yr cobalt metal, up to 2,500 t/yr of cobalt contained in cobalt hydroxide, and up to 1,500 t/yr of cobalt contained in cobalt sulfate solution. The agreement expired in 2012, but reportedly was replaced by an annual supply agreement that would expire in June 2013. In 2012, Norilsk began construction of a cobalt refinery at Monchegorsk, where the hydroxide would be refined to cobalt cathode (table 7) (Darton Commodities Ltd., 2013, p. 12; OJSC MMC Norilsk Nickel, 2013a, p. 28, 36, 65).

South Africa.—The Nkomati nickel sulfide mine (a joint venture of African Rainbow Minerals Ltd. and Norilsk) produced 998 t of cobalt in nickel concentrate in 2012, nearly twice the 513 t produced in 2011. The concentrate was processed at Norilsk's Harjavalta refinery in Finland (African Rainbow Minerals Ltd., 2013, p. 64; undated).

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-metal refinery near Rustenburg, Northwest 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-metal refineries and produced semirefined nickel sulfate containing cobalt.

Spain.—Lundin Mining Corp. restarted mining nickel sulfide ore from its Aguablanca open pit in Badajoz Province in August 2011 and restarted concentrate production in August 2012 (Lundin Mining Corp., 2013, p. 20).

Sweden.—Minpro AB (Strassa) introduced a new type of ferrotungsten to the market. The product, named quick mix ferrotungsten, was produced by leaching grinding sludge and spent cemented carbide tools. Cobalt from the cemented carbide was recovered as cobalt hydroxide cake and sold to cobalt producers worldwide (Advantage Environment, 2013).

Uganda.—Kasese Cobalt Co. Ltd. produced cobalt cathode from stockpiled pyrite concentrates using a bacterial leaching-SX-EW process at its cobalt refinery in southwestern Uganda. In 2012, production was lower than planned because of reduced water availability during the April–June quarter. At current production rates, the stockpile was expected to be exhausted in 2013 (MFC Industrial Ltd., 2012).

United Kingdom.—The British Geological Survey updated its evaluation of the risk of supply disruption for chemical elements or element groups of economic value. On a scale where 1 was very low risk and 10 was very high risk, cobalt had a supply risk index of 7.6, based on a number of factors including geographic concentration of current production and political stability of the leading sources of production (British Geological Survey, 2012).

Zambia.—Estimated Zambian cobalt mine production decreased in 2012 compared with that of 2011, mainly owing to decreases in estimated cobalt production from Konkola Copper Mines Plc (KCM) and Barrick Gold Corp.'s Lumwana copper mine. Refined production of cobalt increased, however, owing to increased imports of cobalt feed materials from Congo (Kinshasa).

Mopani Copper Mines produced 230 t of cobalt metal at its Nkana cobalt refinery, compared with 890 t in 2011. Approximately 30% of the cobalt produced originated from company sources, mainly the Nkana underground copper-cobalt mine, and 70% originated from third party sources. The refinery was placed on care-and-maintenance status in July, owing to a lack of suitable feed from Mopani's operations and declining cobalt prices on the international market (Banda, 2013; Glencore International plc, 2013, p. 51).

Chambishi Metals plc (90% ENRC and 10% ZCCM Investments Holdings Plc) produced 5,435 t of cobalt metal at its Chambishi refinery, 12% more than the 4,856 t produced in 2011. The refinery processed copper-cobalt concentrate from ENRC's operations in Congo (Kinshasa) and cobalt-containing materials from other companies, including cobalt hydroxide from Tenke Fungurume (Eurasian Natural Resources Corp. PLC, 2013, p. 37; Cobalt Development Institute, 2013a; Darton Commodities Ltd., 2013, p. 9).

KCM 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. Most of this alloy reportedly was exported to China for refining. Darton Commodities Ltd. (2014, p. 17) estimated that KCM's production decreased to 1,600 t of contained cobalt in 2012, from 2,400 t in 2011. During the year, KCM commissioned a

second cobalt recovery furnace at the smelter, with a production capacity of 1,350 to 1,400 t/yr of cobalt (Vedanta Resources plc, 2012a, p. 49; 2012b, p. 5).

China Nonferrous Metal Mining Group Co. 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. CNMC planned to recover cobalt from the CCS's smelter slag (table 7) and worked toward producing a cobalt concentrate from CLM's Baluba beneficiation plant (China Nonferrous Metal Mining Group Co. Ltd., 2012, p. 2–3, 150, 172).

Glencore's Sable Zinc Kabwe Ltd. copper electrowinning plant processed feed from third party sources and produced 710 t of cobalt in carbonate in 2012 (160 t in 2011) (Glencore International plc, 2013, p. 51).

Albidon Ltd.'s Munali nickel mine in southern Zambia remained on care-and-maintenance status. Majority shareholder Jinchuan provided funding while Albidon evaluated the mine's future viability (Albidon Ltd., 2012).

Zimbabwe.—The Mimosa platinum mine (Aquarius Platinum Ltd. and Impala Platinum Holdings Ltd.) produced 88 t of cobalt (86 t in 2011). The concentrates were refined by Impala in South Africa (Aquarius Platinum Ltd., 2012, p. 12; 2013, p. 12). The Bindura Nickel Corp. (BNC) Shangani and Trojan nickel sulfide mines, smelter, and refinery remained on care-and-maintenance status while the company sought funding to restart operations. Following a successful share issue, BNC recapitalized and restructured, which provided the necessary funds to begin restarting operations at the Trojan Mine (Mwana Africa PLC, 2012, p. 3).

Outlook

Trends in cobalt consumption closely follow those of global industrial production. Increasing consumption, particularly for chemical applications such as rechargeable batteries, is forecast to result in increases in cobalt consumption of about 6% per year from 2013 through 2017. During the first half of 2013, the world production of refined cobalt was estimated to be 11% higher than that of the first half of 2012. China showed a large increase in production and the Ambatovy operation in Madagascar, which began producing during the second half of 2012, ramped up its output. In the next few years, global increases in supply from existing producers and new projects are forecast to outpace increases in consumption (Cobalt Development Institute, 2013b; Kotseras, 2013, p. 14–16).

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TABLE 1
SALIENT COBALT STATISTICS¹

(Metric tons, cobalt content, unless otherwise specified)

	2008	2009	2010	2011	2012	
United States:						
Consumption:						
Reported	8,820	7,470	8,030	9,100	8,420	
Apparent	10,100	7,580	10,300	9,230	9,520	
Imports for consumption	10,700	7,680	11,100	10,600	11,100	
Exports	2,850	2,440	2,640	3,390	3,760	
Stocks, December 31:						
Industry ²	582	525	630	784	721	
London Metal Exchange (LME), U.S. warehouse	XX	XX	23	43	51	
U.S. Government ³	473	293	301	301	301	
Price, metal						
U.S. Spot ⁴	dollars per pound	39.01	17.86	20.85	17.99	14.07
LME, cash ⁵	do.	XX	XX	XX	16.01	13.06
World:						
Production:						
Mine	79,900 ^r	79,900 ^r	107,000 ^r	110,000 ^r	103,000 ^e	
Refinery	57,600 ^r	61,800 ^r	79,500 ^r	82,400 ^r	77,900	
Stocks, December 31, LME ⁶	XX	XX	278	304	429	

^eEstimated. ^rRevised. do. Ditto. XX Not applicable.

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

²Stocks held by cobalt processors and consumers.

³Defense Logistics Agency Strategic Materials. Data are uncommitted material only.

⁴Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week or Platts Metals Daily.

⁵Annual average mean of the cash buyer price and cash seller and settlement price, minimum 99.3% cobalt briquettes, cathode, ingot, or rounds, converted from dollars per metric ton.

⁶Stocks held in Asia, Europe, and the United States.

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

(Metric tons, cobalt content)

	2011	2012
Consumption by end use:		
Steels	548	548
Superalloys	4,650	4,040
Alloys, excludes steels and superalloys:		
Magnetic alloys	313	285
Other alloys ³	438	414
Cemented carbides ⁴	773	774
Chemical and ceramic uses	2,310	2,300
Miscellaneous and unspecified	63	63
Total	9,100	8,420
Consumption by form:		
Chemical compounds, organic and inorganic ⁵	2,220	2,210
Metal	4,670	4,050
Purchased scrap	2,210	2,160
Total	9,100	8,420
Stocks, December 31: ⁶		
Chemical compounds, organic and inorganic ⁵	202	179
Metal	W	W
Purchased scrap	W	W
Total	784	721

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 nonferrous alloys, welding materials, and wear-resistant alloys.

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	2011			2012		
	Gross weight (metric tons)	Cobalt content ² (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content ² (metric tons)	Value (thousands)
Metal ³	8,020	8,020	\$296,000	8,750	8,750	\$264,000
Oxides and hydroxides	2,590	1,870	61,200	2,320	1,670	51,200
Other:						
Acetates	305	73	2,570	219	53	1,530
Carbonates	649	298	12,400	809	372	13,600
Chlorides	102	26	965	89	22	498
Sulfates	1,140	307	9,360	689	186	5,360
Total	12,800	10,600	383,000	12,900	11,100	336,000

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

²Estimated from gross weights.

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 (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)
2011:															
Australia	792	792	\$27,900	--	--	--	--	--	--	--	--	--	792	792	\$27,900
Belgium	131	131	5,480	426	307	\$13,500	--	--	--	--	--	--	557	438	19,000
Brazil	387	387	12,800	--	--	--	63	19	\$770	449	405	13,600	449	405	13,600
Canada	231	231	10,000	1,210	870	20,100	--	--	--	1,440	1,100	30,100	1,440	1,100	30,100
China	1,820	1,820	65,800	308	222	8,460	231	69	2,060	2,360	2,110	76,300	2,360	2,110	76,300
Congo (Kinshasa)	268	268	9,060	21	15	633	--	--	--	289	283	9,690	289	283	9,690
Finland	265	265	13,200	325	234	9,290	1,170	418	15,600	1,760	917	38,200	1,760	917	38,200
France	11	11	699	(6)	6	658	4	1	22	15	10	788	29	15	848
Germany	3	3	168	8	6	516	516	139	4,440	675	298	10,000	675	298	10,000
India	159	159	5,580	--	--	335	--	--	--	224	221	8,950	224	221	8,950
Japan	216	216	8,610	8	6	--	--	--	--	200	200	6,940	200	200	6,940
Morocco	200	200	6,940	--	--	--	--	--	--	1,140	1,140	42,300	1,140	1,140	42,300
Norway	1,140	1,140	42,300	--	--	--	--	--	--	(6)	8	38,500	1,020	1,020	38,500
Russia	1,020	1,020	38,500	--	--	--	--	--	--	--	--	6,150	173	173	6,150
South Africa	173	173	6,150	--	--	--	--	--	--	--	--	2,640	81	81	2,640
Uganda	81	81	2,640	--	--	--	--	--	--	184	51	2,130	537	325	12,900
United Kingdom	66	66	2,590	288	207	8,180	--	--	--	--	--	1,040	1,040	1,040	36,900
Zambia	1,040	1,040	36,900	--	--	--	--	--	--	5	2	98	22	20	932
Other	18 ^r	18 ^r	829 ^r	(6)	(6)	5	5	2	98	22 ^r	20 ^r	932 ^r	22 ^r	20 ^r	932 ^r
Total	8,020	8,020	296,000	2,590	1,870	61,200	2,190	704	25,300	12,800	10,600	383,000	12,800	10,600	383,000
2012:															
Australia	701	701	19,100	--	--	--	--	--	--	--	--	19,100	701	701	19,100
Austria	12	12	727	--	--	--	--	--	--	12	12	727	12	12	727
Belgium	110	110	2,830	529	381	14,300	--	--	--	640	491	17,100	640	491	17,100
Brazil	525	525	14,600	2	1	31	40	13	498	567	540	15,200	567	540	15,200
Canada	425	425	14,300	542	390	7,230	--	--	--	967	815	21,500	967	815	21,500
China	1,920	1,920	56,100	245	176	5,680	141	59	2,190	2,310	2,160	63,900	2,310	2,160	63,900
Congo (Kinshasa)	81	81	2,190	2	1	48	--	--	--	82	82	2,230	82	82	2,230
Finland	446	446	17,000	459	331	11,500	955	370	12,200	1,860	1,150	40,700	1,860	1,150	40,700
France	11	11	631	--	--	--	69	17	286	80	28	917	80	28	917
India	47	47	1,450	--	--	--	342	92	2,720	389	140	4,170	389	140	4,170
Japan	689	689	20,300	(6)	(6)	11	--	--	--	689	689	20,300	689	689	20,300
Korea, Republic of	52	52	1,510	6	4	169	1	(6)	5	59	56	1,690	59	56	1,690
Morocco	170	170	4,750	--	--	--	--	--	--	170	170	4,750	170	170	4,750
Norway	1,140	1,140	34,600	--	--	--	--	--	--	1,140	1,140	34,600	1,140	1,140	34,600
Peru	--	--	--	--	--	--	30	14	669	30	14	669	30	14	669
Philippines	--	--	--	18	13	379	--	--	--	18	13	379	--	13	379

See footnotes at end of table.

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

Country of origin	Metal ²		Oxides and hydroxides				Other forms ³			Total		
	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)	Gross weight (metric tons)	Cobalt content ⁴ (metric tons)	Value ⁵ (thousands)
Russia	903	903	\$27,000	--	--	--	(6)	(6)	\$3	903	903	\$27,000
South Africa	368	368	12,500	13	10	\$404	--	--	--	381	378	12,900
Sweden	14	14	677	--	--	--	--	--	--	14	14	677
Taiwan	16	16	405	--	--	--	32	9	204	48	25	609
Uganda	18	18	466	--	--	--	--	--	--	18	18	466
United Kingdom	32	32	1,700	496	357	11,200	159	49	1,980	687	438	14,900
Zambia	1,070	1,070	31,300	--	--	--	--	--	--	1,070	1,070	31,300
Other	6	6	239	6	4	268	38	9	190	49	19	696
Total	8,750	8,750	264,000	2,320	1,670	51,200	1,810	633	20,900	12,900	11,100	336,000

¹Revised. -- Zero.

²Data are rounded to no more than three significant digits; may not add to totals shown.

³Unwrought cobalt, excluding alloys and waste and scrap; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy.

⁴Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.

⁵Estimated from gross weights.

⁶Customs value.

⁷Less than 1/2 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)
2011	3,060	\$96,300	332	\$2,700	396	\$4,490	7	\$102	3,390	\$104,000
2012:										
Argentina	13	516	(6)	8	--	--	--	--	14	524
Austria	40	1,300	--	--	--	--	--	--	40	1,300
Belgium	98	2,070	45	879	117	2,590	--	--	158	5,540
Brazil	9	398	--	--	--	--	19	199	14	597
Canada	325	5,780	1	24	--	--	--	--	326	5,800
China	81	2,320	315	1,090	--	--	(6)	4	308	3,410
France	819	19,300	(6)	5	--	--	--	--	819	19,300
Germany	224	11,900	(6)	3	--	--	--	--	224	11,900
Hong Kong	38	1,790	2	67	--	--	--	--	39	1,860
India	93	3,820	--	--	57	495	--	--	107	4,310
Ireland	628	17,400	1	11	--	--	--	--	628	17,400
Italy	9	515	(6)	5	--	--	--	--	10	520
Japan	309	10,900	--	--	--	--	--	--	309	10,900
Korea, Republic of	99	5,110	2	90	6	55	--	--	102	5,250
Luxembourg	37	2,190	--	--	--	--	--	--	37	2,190
Mexico	2	144	29	265	25	204	2	30	30	643
Netherlands	134	3,910	(6)	9	--	--	--	--	134	3,920
Norfolk Island	19	608	--	--	--	--	--	--	19	608
Saudi Arabia	5	383	--	--	--	--	--	--	5	383
Singapore	16	1,010	--	--	--	--	--	--	16	1,010
South Africa	7	318	--	--	--	--	--	--	7	318
Taiwan	14	721	--	--	--	--	--	--	14	721
Thailand	12	689	--	--	--	--	--	--	12	689
Tunisia	7	215	--	--	--	--	--	--	7	215
United Arab Emirates	5	425	--	--	--	--	--	--	5	425
United Kingdom	348	11,200	(6)	3	--	--	(6)	6	348	11,200
Other	29	1,420	2	84	--	--	--	--	30	1,510
Total	3,420	106,000	397	2,540	205	3,350	22	238	3,760	113,000

-- 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 weights.

⁶Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 6
 WORLD ANNUAL COBALT REFINERY
 CAPACITY, DECEMBER 31, 2012^{1,2}

(Metric tons, cobalt content)

Country	Capacity
Australia	6,700
Belgium	1,500
Brazil ^c	3,000
Canada ^c	6,420
China ^c	50,000
Congo (Kinshasa) ^c	12,400
Finland ^c	13,000
France	500
India ^c	2,060
Japan ^c	2,600
Madagascar	5,600
Morocco	2,000
Norway	5,200
Russia ^c	6,000
South Africa ^c	1,400
Uganda	720
Zambia	8,800
Total	128,000

^cEstimated.

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, 2013–17^{1,2}

Projected year of first production	Country	Project and company ³	Project type ⁴	Principal metal	Ore/feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2013	Australia	Barnes Hill Nickel Developments Ltd. (Metals Finance Ltd. subsidiary) and Proto Resources & Investments Ltd.	new mine and ATML processing plant	nickel	nickel-cobalt laterite ore	250 ^{r,e}	Co sulfate.
2013	Do.	Rocklands Group Copper CuDeco Ltd.	new mine and beneficiation plant	copper	copper-cobalt-gold oxide and sulfide ore	NA	Cobaltic-pyrite concentrate.
2013 ^f	Canada	Nunavik Nickel Canadian Royalties Inc. (Jien Canada Mining Ltd.)	do.	nickel	nickel-copper-cobalt platinum-group metals sulfide ore	425 ⁵	Nickel concentrate.
2013	Do.	Raglan Mine Xstrata Nickel	expansion of existing mine	do.	do.	NA	Do.
2013	Do.	Voisey's Bay Long-Harbour commercial nickel processing plant Vale S.A.	new refinery	do.	nickel-copper-cobalt sulfide concentrate	2,500	Cobalt cathode.
2013	Congo (Kinshasa)	Pumpi (Project Cobalto-Cuprifere) La Miniere de Kalukundi [Groupe Managem and Congo Stars Mining SARL (Costamin)]	new mine	copper	copper-cobalt ore	NA	Copper-cobalt concentrate.
2013	Do.	Tenke Fungurume, phase 2 Freeport-McMoRan Copper & Gold Inc., Lundin Mining Corp., and La Générale des Carrières et des Mines (Gécamines)	expansion of existing operation	do.	copper-cobalt oxide ore	15,000 ⁶	Cobalt hydroxide.
2013 ^f	Do.	WOL-SX-EW refinery, updated phase 4 expansion Katanga Mining Ltd., La Générale des Carrières et des Mines (Gécamines), and La Société Immobilière du Congo	expansion of new beneficiation plant and SX-EW refinery	do.	copper-cobalt oxide and sulfide ore	22,000	Do.
2013	Japan	Niihama expansion Sumitomo Metal Mining Co., Ltd.	expansion of existing refinery	nickel	nickel-cobalt sulfide and nickel matte	4,500 ⁶	Cobalt cathode.
2013	Philippines	Taganito Sumitomo Metal Mining Co., Ltd., Nickel Asia Corp., and Mitsui & Co., Ltd.	new HPAL processing plant	do.	nickel-cobalt laterite ore	2,600	Nickel-cobalt sulfide.
2013 ^{f,e}	South Africa	Jubilee Smelting and Refining (Middelburg) smelter Jubilee Platinum plc	adapt existing smelter to include ConRoast process	platinum-group metals-nickel	platinum-group metals concentrates and sludge	NA	Nickel-copper-cobalt-iron-platinum-group metals alloy.
2013	Vietnam	Ban Phuc Asian Mineral Resources Ltd. and Son La Mechanical Engineering Joint Stock Company	new mine and beneficiation plant	nickel	nickel-copper-cobalt sulfide ore	200	Nickel-copper-cobalt-concentrate.

See footnotes at end of table.

TABLE 7—Continued
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, 2013–17^{1,2}

Projected year of first production	Country	Project and company ³	Project type ⁴	Principal metal	Ore/feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2013–14	Congo (Kinshasa)	Kakanda North Boss Mining Sprl [Eurasian Natural Resources Corp. PLC and La Générale des Carrières et des Mines (Gécamines)]	new mine and beneficiation plant	copper	copper-cobalt oxide and sulfide ore	NA	Copper-cobalt concentrate.
2014	Belgium	Olen n.v. Umicore, s.a.	expansion of existing refinery	NA	NA	NA	Cobalt metal powder.
2014	Congo (Kinshasa)	Etoile Leach SX-EW plant Chemaf SPRL	new refinery	copper	copper-cobalt oxide and sulfide ore	4,500	Cobalt hydroxide.
2014 ^{5,7}	Mexico	El Boleo Minera y Metalúrgica del Boleo, S.A.P.I. de C.V. (Korean Consortium ⁸ and Baja Mining Corp.)	new mine and refinery	do.	copper-cobalt-zinc-manganese oxide and sulfide ores	2,400	Cobalt cathode.
2014	Philippines	Acoje, stage 1a ENK PLC (formerly European Nickel PLC) and DMCI Mining Corp.	new mine and atmospheric tank leaching operation	nickel	nickel-cobalt laterite ore	530 ^{e,5}	Cobalt carbonate.
2014 ^f	Do.	Mindoro Nickel, stage 1 Intex Resources ASA	new mine, beneficiation plant, ATML and HPAL processing plant, and refinery	do.	do.	1,200	Cobalt sulfate.
2014 ^{r,e}	United States (Idaho)	Idaho Cobalt Formation Metals Inc.	new mine and refinery	cobalt	stratiform cobalt-copper-gold ore	1,525 ⁵	Cobalt cathode.
2014 ^f	United States (Michigan)	Eagle Kennecott Eagle Minerals Co.	new mine, crusher, and rehabilitated beneficiation plant	nickel-copper	nickel-copper sulfide ore	400 ^e	Copper-nickel concentrate.
2014	Zambia	Chambishi Copper Smelter Chambishi Copper Smelter Co., Ltd. (China Nonferrous Mining Corp. Ltd. And Yunnan Copper Industry Group Co. Ltd.) and Hunan Shijiyintianxinye Technology Co., Ltd.	add new bioleaching plant to existing smelter	copper	Copper-cobalt converter slag	500–700	Cobalt cathode.
2014	Do.	Nkana Cobalt Plant Mopani Copper Mines Plc	expansion of existing refinery	cobalt	cobalt concentrates and intermediates	7,000 ⁶	Do.
2015	Australia	Mt. Thirsty Barra Resources Ltd. and Fission Energy Ltd.	new mine and atmospheric leaching plant	nickel	manganese-nickel-cobalt oxide ore	2,700	Nickel-cobalt sulfide.
2015 ^f	Canada	NICO Fortune Minerals Ltd.	new mine, relocated and refurbished beneficiation plant, and refinery	gold	gold-cobalt-bismuth-copper ore	1,575 ^{r,5}	Cobalt cathode or sulfate.
2015 ^f	Congo (Kinshasa)	Roan Tailings Reclamation (formerly Kolwezi Tailings) Eurasian Natural Resources Corp. Plc, La Générale des Carrières et des Mines (Gécamines), and Government of Congo (Kinshasa)	new refinery	copper	copper-cobalt tailings	10,000	Cobalt hydroxide.

See footnotes at end of table.

TABLE 7—Continued
COBALT: SELECTED PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BY 2013–17^{1,2}

Projected year of first production	Country	Project and company ³	Project type ⁴	Principal metal	Ore/feed type	Annual production capacity (metric tons, cobalt content)	Cobalt product
2015 ^t	Russia	Monchegorsk OJSC MMC Norilsk Nickel	new refinery	nickel	cobalt hydroxide	3,000	Cobalt cathode.
2015 ^{t, e}	Tanzania	Kabanga Barrick Gold Corp. and Xstrata Nickel	new mine and beneficiation plant	do.	nickel sulfide ore	NA	Nickel concentrate.
2015 ^{t, e}	United States (Minnesota)	NorthMet, phase 1 PolyMet Mining Corp.	do.	copper	copper-nickel-platinum-group metals sulfide ore	360	Do.
2015	Zambia	Synclinorium Mopani Copper Mines Plc	expansion of existing mine	do.	copper-cobalt ore	NA	Copper-cobalt ore.
2016 ^{e, 9}	Australia	Wingellina Nickel Metals X Ltd.	new mine and HPAL processing plant	nickel	nickel-cobalt laterite ore	3,000 ⁵	Nickel-cobalt hydroxide.
2016 ^{t, e}	Cameroon	Nkamouna Geovic Mining Corp. and Société National d'Investissement du Cameroun	new mine and processing plant	cobalt	do.	6,100 ⁵	Cobalt-nickel sulfide.
2016 ^{t, e}	Canada	Minago Victory Nickel Inc.	new mine and beneficiation plant	nickel	nickel-copper-cobalt platinum-group metals-precious metals sulfide ore	230 ^{e, 5}	Nickel concentrate.
2016 ^t	Congo (Kinshasa)	Boss Mining expansion Boss Mining Sprl [Eurasian Natural Resources Corp. PLC and La Générale des Carrières et des Mines (Gécamines)]	expansion of existing operation	copper	copper-cobalt oxide ore	NA	Copper-cobalt concentrate.
2016 ^e	Philippines	Acoje, stage 1b ENK PLC (formerly European Nickel PLC) and DMCI Mining Corp.	do.	nickel	nickel-cobalt laterite ore	645 ^{e, 5, 10}	Cobalt carbonate.
2016 ⁹	Tanzania	Dutwa African Eagle Resources Plc.	new mine and atmospheric agitated acid leaching processing plant	do.	nickel laterite ore	NA	Nickel-cobalt hydroxide or nickel-cobalt sulfide.
2017	Indonesia	Weda Bay, phase 1 Strand Minerals (Indonesia) Pte. Ltd. (Eramet S.A., Mitsubishi Corp., and Pacific Metals Co. Ltd.) and PT Antam Tbk	new mine and ATML processing plant	do.	nickel-cobalt laterite ore	2,200 ^e	Cobalt sulfide.

^eEstimated. ^tRevised. 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 2012. Actual startup dates may be postponed owing to economic or other factors. Additional projects might produce cobalt by 2017, but not enough information was available to include them.

³SX-EW solvent extraction-electrowinning. WOL-SX-EW whole ore leach-solvent extraction-electrowinning.

⁴ATML Atmospheric leach. HPAL High pressure acid leach. SX-EW solvent extraction-electrowinning.

⁵Average production.

⁶Total capacity following expansion.

⁷Cobalt production would begin after copper production reaches a steady rate.

⁸The 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.

⁹Startup date provided before project postponement was announced; no information is available on the length of delay.

¹⁰Total average production following expansion.

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

(Metric tons, cobalt content)

Country ³	2008	2009	2010	2011	2012 ^e
Australia ⁴	4,785 ^r	4,345 ^r	3,852 ^r	3,848 ^r	5,882 ⁵
Botswana ⁶	337	342 ^r	272 ^r	149	195 ⁵
Brazil	2,631	2,075	3,139	3,623 ^r	3,900 ^p
Canada ⁷	8,953	3,919	4,636	6,836 ^r	6,625 ^{p,5}
China ^e	6,630	6,000	6,380 ^r	6,800	7,000
Congo (Kinshasa) ^{e,8}	32,300	40,000	60,000	60,000	51,000
Cuba ^{e,9}	4,000 ^r	4,600 ^r	4,800 ^r	5,100 ^r	4,900
Finland ^e	105 ⁵	27	140	500 ^r	635
Indonesia ^{e,10}	1,300	1,200	1,600	1,600	1,700
Madagascar ^{e,11}	--	--	165	500	630
Morocco ^{e,12}	1,700	2,200	3,110 ⁵	2,159 ⁵	1,800
New Caledonia ^{e,13}	2,110	2,000	2,850	3,100 ^r	2,620
Papua New Guinea ¹⁴	--	--	--	--	469 ⁵
Philippines ^e	1,200	1,500	2,200	2,200	2,600
Russia ^{e,12}	6,200	6,100	6,200	6,100 ^r	6,300
South Africa ^e	590	610	1,800	1,600	2,500
Zambia ^{e,15}	7,000	4,900	6,200	5,400	4,200
Zimbabwe ¹⁶	85 ^e	74	79	86	88 ⁵
Total	79,900 ^r	79,900 ^r	107,000 ^r	110,000 ^r	103,000

^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 November 25, 2013. 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 figure.

⁶Reported cobalt content of pelletized nickel-copper matte.

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.

¹¹Datum for 2012 is estimated cobalt content of reported mixed sulfide production.

¹²Cobalt content of concentrates.

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 content of concentrates and slags.

¹⁶Cobalt content of intermediate products produced in Zimbabwe from nickel and platinum ores mined in Zimbabwe; excludes some probable unreported mine production in Zimbabwe and cobalt in products produced from materials originating in Botswana.

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

(Metric tons, cobalt content)

Country and form	2008	2009	2010	2011	2012
Australia, metal powder and oxide hydroxide ^c	3,620	4,050	4,120	4,720	4,860
Belgium, metal powder, oxide, hydroxide ³	3,020	2,150	2,600	3,187	4,200
Brazil, metal	1,215	1,012	1,369	1,614 ^r	1,750 ^p
Canada, metal, metal powder, oxide	5,637	4,918	4,711	6,038	5,981 ^p
China, metal, metal powder, oxide, salts ^{e,4}	18,200	25,500	35,900	35,000	29,800
Congo (Kinshasa), metal ⁵	1,049	2,950	4,222 ^r	3,103 ^r	3,021
Finland, metal powder and salts ⁶	9,645	8,970 ^r	9,429 ^r	10,627 ^r	10,562
France, chloride	311	368	302	354	326
India, metal and salts	858	1,001	1,187	1,299	800
Japan, metal	1,071	1,332	1,935	2,007	2,542
Madagascar, metal powder	--	--	--	--	493
Morocco, metal and oxide	1,791 ^r	1,600	1,615 ^r	1,788	1,314
Norway, metal	3,719	3,510	3,208	3,067	2,969
Russia, metal	2,502	2,352	2,460	2,337	2,186
South Africa, metal powder and sulfate	244	238	840 ^r	862 ^r	1,102
Uganda, metal	662 ^r	389 ^r	568 ^r	673 ^r	374
Zambia, metal	4,049	1,506	5,026	5,746 ^r	5,665 ^p
Total	57,600 ^r	61,800 ^r	79,500 ^r	82,400 ^r	77,900

^cEstimated. ^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 November 25, 2013. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

³Production reported by n.v. Umicore s.a.; includes production from China that is not otherwise included.

⁴Production from domestic and imported ores, concentrates, and intermediate materials; excludes production by n.v. Umicore s.a. that is included under Belgium.

⁵Excludes production of cobalt in alloys, carbonate, hydroxide, and other materials that would require further refining.

⁶Production reported by the Geological Survey of Finland.