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Nickel

By Michele E. McRae

Domestic survey data and tables were prepared by Kristi J. Simmons, statistical assistant.

Reported nickel consumption (primary plus secondary) in the United States in 2017 increased by 3% to 223,000 metric tons (t) compared with a revised 216,000 t in 2016 (table 1). U.S. apparent consumption of primary nickel was 140,000 t, or about 6% of the 2.19 million metric tons (Mt) of world consumption reported by the International Nickel Study Group (INSG). Stainless-steel production accounted for 40% of U.S. primary consumption of nickel in contrast with 66% globally. This was likely a reflection of the large number of specialty metal companies and a readily available supply of stainless-steel scrap in the United States (table 4). U.S. industry was estimated to have melted 122,000 t of nickel contained in scrap, a slight increase from 120,000 t (revised) in 2016 (table 2) (Nickel Institute, 2016, p. 14; International Nickel Study Group, 2018b, p. A–1).

World mine production of nickel was 2.16 Mt of contained nickel in 2017, an 8% increase compared with 2.00 Mt (revised) in 2016 (table 10). According to Platts Metals Week, after fluctuating in the first half of 2017, the London Metal Exchange Ltd. (LME) average monthly cash price for nickel metal trended upward for the second half of 2017, and averaged $10,403 per metric ton for the year, an 8% increase compared with $9,594 per metric ton in 2016 (table 1). Daily stocks of nickel metal held in LME-approved warehouses worldwide decreased slightly to 366,612 t at yearend 2017 compared with stocks at yearend 2016.

Stainless steel accounted for about 66% of global primary nickel (nickel produced from mined material rather than that recovered from recycled scrap) consumption. World production of stainless steel and heat-resistant steel was 48.1 Mt in 2017, a 5% increase compared with that in 2016. China was the leading producer of stainless steel, accounting for about 54% of world output, as well as the leading consumer (International Stainless Steel Forum, 2020, p. 7, 12). On a global basis, nonferrous alloys accounted for about 10% of primary nickel use; electroplating and other surface finishing, 9%; alloy steels other than stainless, 8%; batteries, catalysts, and specialty chemicals, 4%; and foundry products, 3% (Nickel Institute, 2016, p. 14).

Legislation and Government Programs

U.S. Coinage.—Dimes, half dollars, nickels, one-dollar coins, and quarters contain nickel in the form of either cupronickel or manganese-brass alloy. Total nickel consumption for coin production was 3,236 t in 2017, a 10% decrease compared with that in 2016 (U.S. Mint, undated a, b).

The U.S. International Trade Commission (USITC) determined that it would continue to impose antidumping duties on certain stainless-steel sheet and strip in coils from Japan, the Republic of Korea, and Taiwan, and a countervailing duty on stainless-steel sheet and strip in coils from the Republic of Korea. These duties have been in place since 1999 and were reviewed approximately every 5 years. The USITC found that revocation of the duties would likely lead to continuation or recurrence of dumping and countervailable subsidies and material injury to U.S. industry (U.S. International Trade Commission, 2017a). In a separate action, the USITC determined that because imports of stainless-steel sheet and strip from China were subsidized and sold in the United States at less than fair value, these imports would be subject to antidumping and countervailing duties (U.S. International Trade Commission, 2017b).

Production

The United States had one active nickel mine, the underground Eagle Mine in the Upper Peninsula of Michigan, which began operation in 2014. In 2017, the Eagle Mine produced 22,100 t of nickel in concentrate, an 8% decrease compared with 24,100 t in 2016, but was within the range of the company's production guidance for the year (Lundin Mining Corp., 2018b, p. 2).

Limited quantities of byproduct nickel were recovered at Sibanye Gold Ltd.'s (South Africa) base-metal refinery in Columbus, MT. Leading processors of recycled nickel included International Metals Reclamation Co. Inc.'s (INMETCO's) [owned by American Zinc Recycling LLC (Pittsburgh, PA)] secondary smelter in Ellwood City, PA, and Gladieux Metals Recycling (Freeport, TX) facility in Freeport, TX. The refinery and secondary recovery data from these operations were included with scrap statistics to avoid disclosing company proprietary data (tables 1–5).

No ferronickel was produced from ores in the United States in 2017. Any U.S. ferronickel exports were likely either reexports or material upgraded for special purposes.

Michigan.—Lundin Mining Corp. (Canada) mined the Eagle deposit—a chalcopyrite-pentlandite-rich peridotite intrusion, historically known as the Yellow Dog peridotite, in the Upper Peninsula of Michigan. The ore was processed at the associated Humboldt mill, which produced separate concentrates of copper and nickel sulfides. The two sulfide concentrates were shipped by rail on a dedicated spur from Humboldt Township to the Canadian National Railway line, and then to smelters in Canada or to ports for shipment overseas. In 2017, trade statistics from the U.S. Census Bureau indicated that 55% of total United States nickel concentrates exports went to Canada, 26% to Finland, and 15% to China.

In 2016, Lundin announced an initial resource estimate and results of a Preliminary Economic Assessment of the Eagle East project, which is located approximately 2 kilometers (km; 1 mile) east and 600 meters below the Eagle deposit and part of the same intrusive complex. The company concluded that Eagle East could be developed using existing infrastructure and mining methods similar to those used at the Eagle Mine and began development of an access ramp from the Eagle Mine to the Eagle East extension. Development of the ramp continued in

2017, and in November, the company received approval for an amended mining permit that included development of Eagle East. The project was expected to begin contributing mill feed in 2020 and would extend the Eagle Mine life to at least 2023. According to the company's 2017 resource and reserve statement, the average nickel grade of Eagle East's probable reserves was 3.7% nickel, approximately 60% higher than the probable reserves of the original Eagle Mine. Total proven and probable reserves for the project, including Eagle Mine and Eagle East, totaled 130,000 t of nickel, with Eagle East contributing 57,000 t (Lundin Mining Corp., 2018a, p. 23–28, 67).

Minnesota.—PolyMet Mining Corp. (Canada) was waiting for approval to begin developing the copper, nickel, and platinum-group-metal (PGM) NorthMet deposit, located 10 km (6 miles) south of the town of Babbitt in St. Louis County. Ore mined from a proposed open pit would be shipped to the reconditioned Erie mill near Hoyt Lakes, MN, for processing by flotation to produce a marketable concentrate. In phase 2 of the project, the concentrate would be processed in a new hydrometallurgical plant to be built at the Erie site (PolyMet Mining Corp., 2016, p. 14–24).

In January 2017, the U.S. Forest Service issued a final Record of Decision that authorized the company to exchange private lands within the Superior National Forest for Federal lands overlying the NorthMet deposit. By yearend 2017, the Minnesota Department of Natural Resources had released six draft water appropriation permits and two draft dam safety permits for public comment (PolyMet Mining Corp., 2019, p. 5).

Byproduct Smelter and Refinery Production.—In 2017, Sibanye Gold Ltd., trading as Sibanye-Stillwater, completed its acquisition of the Stillwater Mining Co. The company mined PGMs from the J-M Reef in Montana's Beartooth Mountains. Concentrates from the company's two mills (East Boulder and Nye) were trucked to the smelting and refining complex at Columbus, MT, where a PGM filter cake and byproduct crystalline nickel sulfate containing minor amounts of cobalt were produced (Sibanye Gold Ltd., 2017; Stillwater Mining Co., 2017, p. 7–8, 21).

Secondary Production.—INMETCO operated the only secondary smelter in North America dedicated to recovering chromium- and nickel-containing waste and scrap. The smelter at Ellwood City, PA, produced an iron-base remelt alloy that typically averaged 13% chromium and 12% nickel. Stainless-steel producers used the remelt alloy as a substitute for ferrochromium and ferronickel. INMETCO was capable of processing a wide range of nickel-bearing wastes including flue dust, grinding swarf, mill scale, and shot blast generated during the manufacturing of stainless steel. The complex also accepted filter cakes, plating solutions, spent pickle liquor, sludges, and all types of spent nickel-containing batteries (Horsehead Holding Corp., 2015, p. 8–10).

Gladieux Metals Recycling processed spent catalysts from petroleum refineries. The Freeport, TX, facility (formerly owned by Gulf Chemical & Metallurgical Corp.) treated nickel-molybdenum and cobalt-molybdenum hydrotreating catalysts that had been contaminated by nickel and vanadium contained in the crude oil. Gladieux first roasted and leached the spent catalysts to recover the molybdenum and vanadium. The nickel-and-alumina residue was then converted to a marketable nickel-cobalt-molybdenum alloy in a direct-current electric arc furnace (Stephan, 2013).

Consumption

Reported primary nickel consumption in the United States was 101,000 t in 2017, a 5% increase compared with 96,000 t (revised) in 2016 (table 1). The estimated value of reported primary nickel consumption was $1.05 billion, a 14% increase compared with that in 2016, owing to increases in reported consumption and in the annual average LME cash price. U.S. industry consumed 10,300 t of ferronickel in 2017, of which more than 99% was used in stainless, heat-resistant, or specialty alloy steels (table 4).

Stainless Steel and Low-Alloy Steels.—In 2017, stainless-steel producers accounted for 40% of reported primary nickel consumption, 70% of total nickel consumption, and 95% of nickel-containing scrap consumption in the United States (table 4). Alloy steels—other than stainless steel—accounted for an additional 7% of U.S. primary nickel consumption. Production of raw stainless steel and heat-resisting steel in the United States increased by 11% to 2.75 Mt. Nickel-bearing grades increased slightly to 1.82 Mt compared with that in 2016 and accounted for 66% of total stainless-steel production (American Iron and Steel Institute, 2017, 2018).

Allegheny Technologies Inc. (ATI) (Pittsburgh, PA) announced the creation of Allegheny and Tsingshan Stainless, a 50–50 joint venture with Tsingshan Holding Group Co. Ltd. (China), to manufacture 60-inch-wide stainless-steel sheet from imported stainless-steel slabs supplied by Tsingshan. The partnership would enable the company to restart operations at its previously idled Direct Roll Anneal and Pickle facility in Midland, PA, which was expected to be fully operational by the second quarter of 2018 (Allegheny Technologies Inc., 2018, p. 3, F–20, F–27).

Superalloys and Related Nickel-Base Alloys.—Of the primary nickel consumed in the United States in 2017, approximately 39% was used to make high-performance superalloys and related nickel-base alloys, primarily for the aerospace, electric power, and petrochemical industries.

Typical applications for nickel-base and superalloys in the aerospace industry include jet engine blades, casings, discs, rings, and vanes. ATI expected that increased fuel efficiency requirements in the commercial aerospace sector would result in increased demand for specialty alloys and metal powders that withstand higher temperatures and continued its strategy of increasing the share of business attributed to higher valued products, including specialty alloys and metallic powders. In 2017, the company reported that sales of differentiated jet engine products increased by 35% compared with sales in 2016. ATI also completed an expansion of its nickel-base powder alloy manufacturing facility in North Carolina and signed a long-term supply agreement with Pratt & Whitney (East Hartford, CT) for isothermal forgings and powder alloys for next-generation jet engines (Allegheny Technologies Inc., 2018, p. F–3, F–20).

Batteries.—Nickel began to be more widely used as a battery material beginning with nickel-cadmium batteries in the 1980s. This trend was accelerated in the 1990s when Toyota Motor Corp. adopted nickel-metal-hydride batteries for use in the hybrid-powered Prius (Nickel Institute, undated). However, batteries accounted for only a small percentage of nickel consumption in 2017, both globally and domestically. Both the Nickel Institute

and the U.S. Geological Survey (USGS) end-use nickel statistics included battery consumption with other miscellaneous uses of nickel. Globally, the Nickel Institute estimated that other uses accounted for 4% of global consumption (Nickel Institute, 2016, p. 14). Domestically, other uses of nickel accounted for 6% of primary nickel consumption (table 4).

Nickel is increasingly used in the cathode of many lithium-ion batteries. Two of the most common cathode formulations are lithium-nickel-cobalt-aluminum (NCA) and lithium-nickel-manganese-cobalt (NMC). The Nickel Institute estimated that in 2016, 39% of lithium-ion batteries contained nickel, but expected that to increase to 58% by 2025 owing to increased demand from electric vehicle batteries and utility-scale energy storage. The primary advantage of nickel-containing cathodes is higher energy density compared with most non-nickel-containing alternatives. Initially, NMC cathodes contained approximately equal amounts of cobalt, nickel, and manganese. In efforts to increase energy density, cathode manufacturers have been increasing the proportion of nickel in the cathode. This had the additional benefit of reducing the reliance on cobalt because as the proportion of nickel increases, the amount of cobalt used decreases. This helps reduce cost and risks associated with cobalt availability (Vale S.A., 2017a; Nickel Institute, 2018).

The USGS annual nickel consumption survey is sent to domestic consumers of primary nickel products. Although the United States was among the leading producers of lithium-ion batteries globally, it lacked the capacity to produce the cathode components for these batteries. Manufacturing of those materials was concentrated in Asia, primarily in China, Japan, and the Republic of Korea (Mayyas and others, 2018, p. 4–5). Consequently, USGS nickel end-use statistics are unlikely to capture expected increased demand from the battery sector.

In October, ZAF Energy Systems, Inc. began production of nickel-zinc batteries at a new facility in Joplin, MO. The plant had the capacity to produce 50 megawatthours of batteries annually and was expected to reach full capacity in 2018. The company expected that the main use for its batteries would be as a replacement for lead-acid batteries in internal combustion automobiles, but could potentially be used on boats, and at remote telecommunications centers and renewable energy installations (Roselund, 2017).

Stocks

Global stocks of nickel metal held in LME-approved warehouses decreased slightly to 366,612 t at yearend 2017 compared with stocks at yearend 2016. Approximately 50%, or 182,262 t, was stored at Johor, Malaysia, an increase of 22% compared with stocks at yearend 2016. Stocks in Rotterdam, the Netherlands—the traditional LME storage point for the European Union and Russia—decreased by 39% to 52,152 t. All stocks in LME-approved warehouses were Class I material (refined products with a nickel content of 99% or greater) (London Metal Exchange Ltd., 2017).

Data collected by the INSG indicated that in December 2017, world nickel producers held 82,300 t of primary nickel stocks, a slight decrease compared with stocks at yearend 2016 (International Nickel Study Group, 2018b, p. A–1). At yearend 2017, U.S. consumer stocks of primary nickel totaled 6,540 t, a slight increase compared with yearend 2016 (tables 1, 5).

Prices

In January 2017, the LME average monthly cash price for nickel metal was $9,980 per metric ton. After fluctuating in the first half of 2017, the average monthly cash price trended upward for the second half of 2017 and averaged $10,403 per metric ton ($4.72 per pound) for the year, an 8% increase compared with $9,594 per metric ton ($4.35 per pound) in 2016 (table 1).

World Review

In 2017, global mine production increased by 8% to 2.16 Mt, and global plant production decreased slightly to 1.97 Mt (tables 10, 12). Mine production from laterite ores increased by approximately 20%. Decreased production from leading sulfide-producing countries, particularly Botswana and Canada, contributed to a 5% decrease in sulfide mine production. Production of nickel metal, which was produced primarily from sulfide ores, decreased by approximately 9% in 2017. Production of ferronickel and nickel chemicals increased by 3% and 26%, respectively. According to the INSG, world consumption of primary nickel increased by 8% to 2.19 Mt (International Nickel Study Group, 2018b, p. A–1).

Australia.—Australia was the sixth-ranked nickel-producing country or locality in the world in terms of mine output and was one of the few countries and (or) localities that mined both sulfide and laterite ores. Australia ranked sixth in plant output and predominantly produced refined metal. In 2017, Australia's mine production decreased by 12% to 178,853 t, and plant production decreased by 14% to 104,000 t (tables 10, 12). Several nickel mines and processing facilities were on care-and-maintenance status, which contributed to reduced production. However, exploration expenditures for nickel and cobalt reportedly tripled compared with those in 2016 (Department of Industry, Innovation and Science, 2018, p. 97–98).

BHP Billiton Ltd.'s Nickel West approved funding to construct a 100,000-metric-ton-per-year (t/yr) nickel sulfate plant at the company's Kwinana Refinery in Western Australia. Debottlenecking projects underway at Kwinana were expected to increase nickel briquet and powder capacity to 84,000 t/yr. The company reported that by yearend 2017 battery precursor manufacturers accounted for nearly 70% of its nickel briquet and powder sales compared with less than 10% in prior years. The company attributed demand for its product to a trend in lithium-ion battery cathodes containing a higher proportion of nickel and the suitability of nickel sulfate production from nickel briquets and powders because of better dissolvability compared with other forms of nickel such as electrolytic nickel (Haegel, 2017, 2018).

In September, First Quantum Minerals Ltd. (Canada) placed its Ravensthorpe operation in Western Australia on care-and-maintenance status owing to the low nickel price (First Quantum Minerals Ltd., 2017). The operation included three open pit laterite mines and a processing plant that used a combination of pressure-acid and atmospheric leaching to produce nickel-cobalt hydroxide (First Quantum Minerals Ltd., undated).

Brazil.—In 2017, Brazil's mine production decreased by 9% to 78,600 t, and total plant production was 68,500 t essentially unchanged from that in 2016. Because Votorantim S.A.'s nickel-cobalt laterite mining operation in Niquelandia, Goias State, and refined nickel and cobalt production at Sao Miguel Paulista, Sao Paulo State, remained on care-and-maintenance status in 2017, all plant production was in the form of ferronickel. Ferronickel was produced at Anglo American plc's Barro Alto and Codemin operations in Goias State and Vale S.A.'s Onça Puma operation in Para State (Anglo American plc, 2015; Vale S.A., 2017b, p. 43).

After reviewing studies related to metal contamination in a river near Vale's Onça Puma operation, a Federal court determined that the company was responsible and ordered mining operations to halt until reparations were made with the indigenous community. Vale appealed the ruling, asserting that the metals were naturally occurring and that there was no evidence of harm to human health (Costa and Samora, 2017). The matter was still unresolved at yearend 2017.

Canada.—Globally, Canada ranked fourth in nickel mine production and third in plant production. Mine production was 214,000 t, a 7% decrease compared with 230,000 t (revised) in 2016. Plant production increased by 3% to 163,000 t (tables 10, 12). Four Provinces had active nickel mines in 2017—Manitoba, Newfoundland and Labrador, Ontario, and Quebec.

Owing to increased capital costs associated with more stringent sulfur dioxide emissions standards, Vale Canada Ltd. intended to phase out smelting and refining operations at Thompson, Manitoba. The company would continue to produce concentrate from sulfide ores extracted from the Birchtree and Thompson Mines, which would be shipped to Vale's Long Harbour and Sudbury refineries (Vale S.A., 2017b, p. 24, 40). In accordance with the plan, Vale shut down the first furnace in 2017 and intended to shut down the remaining furnace in the second half of 2018 (Vale S.A., 2018, p. 44).

China.—China was the leading producer of primary nickel but ranked seventh in mine production (tables 10, 12) and relied on large quantities of imported nickel ore, concentrate, and intermediate products such as matte, nickel-cobalt hydroxide, and nickel-cobalt sulfide to supply its plant production. According to INSG data, most of China's mines are sulfide mines, with reserve grades typically averaging less than 1% nickel (International Nickel Study Group, 2018a, p. B–19—B–27).

In 2017, China's total plant production was 656,000 t, an increase of 5% compared with that of 2016. Production of chemicals and nickel pig iron (NPI) increased, by 37% and 10%, respectively, and production of metal decreased by 8% (table 12).

According to INSG data (International Nickel Study Group, 2018b, p. A–6, B–14—B–15), China was the world's leading consumer of nickel. China's consumption was 1.17 Mt of primary nickel, a 6% increase compared with that in 2016, and accounted for 53% of world consumption in 2017. China's imports of unwrought, unalloyed nickel (Harmonized Schedule number 7502.10) were 235,000 t, a decrease of 35% compared with those in 2016. Imports from Russia accounted for 50%, followed by Australia (14%) and Canada (11%). Gross weight imports of ferronickel (which likely included NPI) increased by 33%, which followed increases of 45% in 2014, 131% in 2015, and 59% in 2016.

Increased production of electric vehicles in China stimulated demand for nickel sulfate which is used in the production of NMC cathode materials. In 2016, production of NMC cathode materials in the country was 65,000 t (which required 106,000 t of nickel sulfate [gross weight] for manufacture), and shipments of batteries using NMC cathode materials accounted for 31% of total lithium-ion battery shipments. Production of NMC cathodes was expected to increase to 100,000 t by yearend 2017. On a gross weight basis, China's total nickel sulfate capacity was 360,000 t/yr in 2017 and was expected to increase to 470,000 t/yr in 2018 (Argus Metals International, 2017, p. 5–6).

Finland.—Terrafame Ltd. (a subsidiary of Terrafame Group Oy, owned by the Government of Finland) continued to ramp up operations at the polymetallic Sotkamo Mine and bioheap-leaching operation and secured funding for continued operations through financing agreements with Galena Asset Management S.A., Sampo plc, and Trafigura Group Ltd. Production of nickel was 20,864 t (contained) in nickel-cobalt sulfide, more than double production in 2016. The company continued to evaluate two alternatives for investment in downstream processing of its nickel-cobalt sulfide including pyrometallurgical processing to produce a ferrous nickel product for the stainless-steel industry and hydrometallurgical processing to produce nickel and cobalt products suitable for use in battery cathodes. In November, the company announced its intention to build a plant with a capacity of 150,000 t/yr of nickel sulfate (gross weight) and 5,000 t/yr of cobalt sulfate (gross weight) to be used in the production of lithium-ion battery precursors (Terrafame Ltd., 2017; 2018, p. 13–14, 22).

PJSC MMC Norilsk Nickel's (Nornickel's) Harjavalta refinery used sulfuric-acid leaching to produce nickel metal in the form of briquets, cathodes, powder, and nickel salts. Harjavalta's nickel production was 59,716 t, an increase of 11% compared with that in 2016, with 59% of nickel produced in briquets, 24% in cathode, 14% in nickel salts, and 2% in powder. In June, Nornickel and BASF SE signed a memorandum of understanding and began to negotiate an agreement under which Norilsk would supply cobalt and nickel from Harjavalta to BASF for the production of lithium-ion battery cathode materials in Europe (BASF SE and PJSC MMC Norilsk Nickel, 2017; PJSC MMC Norilsk Nickel, 2018, p. 84–85).

France.—Eramet Group restarted operations at the Sandouville Refinery in Le Havre which had been temporarily shut down to reconfigure processing to accommodate new feed material. In 2016, Sandouville received its last shipment of matte from its smelter in New Caledonia and instituted a long-term supply agreement with Boliden AB. At yearend 2017, the company was in the process of ramping up operations using the new feed. The newly redesigned facility was expected to produce 13,000 t/yr of high-purity nickel metal, 2,300 t/yr of nickel in salts and liquids, 400 t/yr of cobalt, and 3,000 t/yr of refined iron (Trompiz and Sotinel, 2016; Eramet Group, 2017; 2018, p. 37).

Indonesia.—Through 2013, Indonesia was the leading producer of mined nickel, producing more than 800,000 t/yr (table 10). Production decreased dramatically in 2014 when the Government of Indonesia began to enforce its ban on the

export of key unprocessed metalliferous ores. The regulations, originally enacted as Law No. 4 in 2009, effectively halted all sales of Indonesian nickeliferous direct-shipping ore to overseas producers of ferronickel and NPI. The intent of the ban was to stimulate development of processing facilities that would produce higher valued products within Indonesia (Lederer, 2016). Mines that produced feed material for Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk's (Antam's) ferronickel plant and PT Vale Indonesia Tbk's smelter that produced matte were unaffected by the ban.

In 2017, Indonesia was ranked second in terms of mine production, with production of 345,000 t, an increase of 73% compared with that in 2016 (table 10). Increased production was primarily a result of the continued development and commissioning of NPI smelters in the country and the easing of export restrictions on unprocessed ore beginning in January. To be eligible for a permit to export unprocessed ore, a company had to demonstrate that 30% of its nickel mine production was used as feed at its own processing plant in Indonesia and that any ore to be exported had a nickel content of 1.7% or less. At yearend 2017, the Government of Indonesia reported that it had approved a total of 22.9 Mt of ore exports, but through November, only 3 Mt had been exported. More than $9 billion had been invested in processing facilities resulting in the commissioning of 13 processing plants and an additional 14 facilities that were expanding capacity, planned, or under construction. However, two smelters that used blast furnace technology had stopped operating and another operated only intermittently owing to the increased cost of coal (Home, 2017; Ministry of Energy and Natural Resources, 2017).

Japan.—Japan ranked second in terms of plant production, but all feed material was imported owing to a lack of nickel mines. In 2017, Japan produced a total of 187,000 t of nickel—65,300 t of ferronickel, 61,400 t of metal, 43,600 t of oxide sinter, and 16,800 t of nickel chemicals.

In 2017, Sumitomo Metal Mining Co., Ltd. announced that it would expand capacity for NCA cathode materials at its Isoura plant in Ehime Prefecture to 54,600 t/yr (gross weight). An expansion to 42,600 t/yr from 22,200 t/yr was already underway. The company also announced that it had developed a process to produce nickel sulfate from the recovery of nickel intermediates generated in the production of lithium-ion batteries and had decided to install verification facilities for the mass production of high-purity nickel oxide powder for use in fuel cell electrodes (Sumitomo Metal Mining Co., Ltd., 2017a, b, c).

Korea, Republic of.—SK Innovation Co., Ltd. announced that it had begun to produce mid- and large-sized NMC batteries with a cathode composition that consisted of 80% nickel, 10%, cobalt, and 10% manganese. The company expected that the increased energy density of the new batteries would increase the driving range of an electric vehicle by more than 100 kilometers compared with batteries that used 60% nickel, 20% cobalt, and 20% manganese. The newly designed batteries were expected to be available for use in stationary energy storage by yearend 2017 and for use in electric vehicles beginning in the third quarter of 2018. SK Innovation supplied electric vehicle batteries to BAIC Motor Corp. Ltd., Kia Motors Corp., and Mercedes-Benz (Green Car Congress, 2017).

New Caledonia.—New Caledonia ranked third in mine production and fifth in plant production. Mine production was 215,000 t, a 5% increase compared with that in 2016. Plant production was 73,219 t of nickel in ferronickel and 30,875 t of nickel in nickel oxide sinter. Total plant production was 104,000 t, an increase of 8% compared with that in 2016 (tables 10, 12). New Caledonia also produced nickel-cobalt hydroxide, which was exported for further processing (table 11).

Philippines.—The Philippines was the leading producer of mined nickel, accounting for approximately 17% of world production (table 10). Production was 366,000 t, an increase of 5% compared with that in 2016, even though operations at 13 mines remained idle owing to the Department of Environment and Natural Resources' ongoing audit to determine the adequacy of each operation's environmental protection measures (Department of Environment and Natural Resources, 2018).

Because of a shortage of processing facilities, the country exported most of its production as direct-shipping ore. However, two companies, Coral Bay Nickel (a joint venture among Sumitomo, Mitsui & Co., Ltd., Sojitz Corp., and Rio Tuba Nickel Mining Corp., listed in order of share) and Taganito HPAL Nickel (Sumitomo, Mitsui, and Nickel Asia Corp., listed in order of share), operated hydrometallurgical processing plants that produced mixed nickel-cobalt sulfide compounds that were shipped to Japan for refining.

Russia.—In 2017, Russia was one of the few countries and (or) localities that mined both sulfide and laterite ores. Its mine production totaled 214,000 t of contained nickel, a slight increase compared with that in 2016. Russia produced 157,000 t of refined nickel, an 18% decrease compared with that in 2016. Nornickel, the leading nickel producer in the country, reported total production of 217,000 t in salable nickel products from its plants in Russia and Finland, a decrease of 8% compared with that in 2016. In 2017, the company reduced the contribution of third-party feed material used in its production, increasing nickel feed from Russia to 97% of production, compared with 83% in the prior year. The company's total refined nickel production was adversely affected by the phasing out of refining at the company's Polar Division in 2016 (PJSC MMC Norilsk Nickel, 2018, p. 268–269).

Estimated production of laterite ore decreased by 74% to 1,800 t from 7,000 t in 2016. Laterite ore from mines in the Sverdlovskaya Oblast was processed at OAO Ufaleynikel (Koks Industrial Metallurgical Holding Co.) to produce nickel in granules and at ZAO Rezhnickel (Ural Mining and Metallurgical Co.) for processing into nickel ingots. The processing operations of both companies ceased in 2017, which was attributed to declining ore grades at the Sverdlovskaya mines, low nickel prices, and the increasing cost of coal. The assets of the two companies and Sverdlovskaya mines were reportedly owned by Binbank PAO (Dzhumailo and Yakushko, 2017; International Nickel Study Group, 2018a, p. B–60, C–49—C–50).

Taiwan.—In 2017, Vale Taiwan Ltd.'s Kaoshiung refinery was placed on care-and-maintenance status. The facility had the capacity to produce 18,000 t/yr of Utility® nickel, a 97% nickel metal product used in the production of stainless steel (Vale Canada Ltd., 2012; Vale S.A., 2018, p. 47).

Outlook

From 2007 to 2017, global nickel consumption had a compound annual growth rate of approximately 5% (International Nickel Study Group, 2018b, p. A–1). Stainless steel is expected to continue to be the leading end use of primary nickel. World stainless melt shop production (gross weight) has had a long-term compound annual growth rate of about 6%, climbing from 1 Mt in 1950 to 48.1 Mt in 2017. Chromium-nickel grades (300 series) constitute more than 50% of stainless-steel production (International Stainless Steel Forum, 2020, p. 3, 14).

Increased demand for more-fuel-efficient engines is expected to increase demand for nickel in the transportation manufacturing sector. In the aerospace market, the use of nickel alloys allows for more-fuel-efficient jet aircraft engines by reducing weight while allowing for more thrust and higher operating temperatures. In the automotive sector, austenitic stainless steels have been shown to reduce the weight of individual frame components by 20% compared with carbon steels, leading to improved fuel efficiency (Nickel, 2006, p. 13; 2008, p. 6).

The electric power industry is expected to remain an important consumer of austenitic stainless steel and various nickel-base superalloys—both for new construction and renovation. Global demand for electricity continues to increase and is accelerating as the population of the world increases.

Even the most conservative projections of the emerging demand for nickel-containing batteries in stationary energy storage and electric vehicles anticipate a significant disruption to nickel supply in coming years. Wood Mackenzie Ltd. (2017) estimated that nickel consumption in batteries would increase more than fivefold by 2025, to 275,000 t. Tesla, Inc., for example, which primarily manufactures high-nickel-content batteries, has deployed several utility-scale energy storage systems in recent years and more are expected (Ayre, 2017). The pace of electric vehicle adoption has been accelerating owing to increased regulation of vehicle emissions. Nornickel estimated that electric vehicles use 30 to 110 kilograms of nickel, more than twice as much nickel as hybrid vehicles, and 10 to 30 times more than diesel- and gasoline-powered vehicles (PJSC MMC Norilsk Nickel, 2018, p. 33). Nickel sulfate, the primary nickel-containing material used in the production of cathode precursors, is typically produced from high-purity metal, preferably in the form of briquets, pellets, or powder (Wood Mackenzie Ltd., 2017). Most primary nickel production growth in recent years has been in ferronickel and NPI, which are typically not suitable for battery production. This growth has taken place to the detriment of nickel metal, production of which has been decreasing since 2015 (table 12).

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TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons of contained nickel unless otherwise specified)

		2013	2014	2015	2016	2017
United States:						
Production, concentrate		--	4,300	27,200	24,100	22,100
Secondary recovery from purchased scrap:						
From ferrous scrap		101,000 r	106,000 r	102,000 r	114,000 r	116,000
From nonferrous scrap		8,070	8,990 r	5,600	5,790	5,630
Shipments of purchased scrap[2]		144,000 r	132,000 r	132,000 r	151,000 r	135,000
Exports:						
Ores and concentrates[3]		1,010	3,320	25,400	22,400	20,000
Primary		10,600	10,400	9,610	10,300	11,000
Secondary		61,100	56,300	51,900	63,700	51,500
Imports for consumption:						
Ores and concentrates[3]		3	92	24	(4)	64
Primary		126,000	156,000	130,000	111,000	150,000
Secondary		26,300	39,000	27,100	32,300	38,100
Consumption:						
Reported:						
Primary		110,000 r	113,000	105,000 r	96,000 r	101,000
Secondary, purchased scrap		109,000 r	115,000 r	108,000 r	120,000 r	122,000
Total		219,000 r	228,000 r	213,000 r	216,000 r	223,000
Apparent, primary		111,000	149,000	118,000	104,000	140,000
Apparent primary plus reported secondary		220,000 r	264,000 r	226,000 r	224,000 r	262,000
Stocks, yearend:						
London Metal Exchange Ltd. (LME), U.S. warehouses		3,950	1,560	4,210	5,230	3,780
Consumer, primary		11,900 r	11,200 r	10,600	6,370	6,540
Consumer, secondary		6,670	12,100	8,570	8,690 r	8,160
Total		22,500 r	24,900 r	23,400	20,300 r	18,500
Price:						
Cash, LME:						
Average annual	dollars per metric ton	15,018	16,865	11,831	9,594	10,403
Average annual	dollars per pound	6.812	7.650	5.367	4.352	4.719
Type 304 stainless-steel scrap, gross weight:[5]						
Average annual	dollars per metric ton	1,574	1,714	1,240	1,075	1,304
Average annual	dollars per long ton	1,599	1,742	1,260	1,092	1,325
World, mine production		2,610,000 r	2,140,000 r	2,120,000 r	2,000,000 r	2,160,000

rRevised. -- Zero.
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits, except prices; may not add to totals shown.
[2]Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.
[3]Nickel ores and concentrates (Harmonized Tariff Schedule of the United States code 2604.00.0040). Source: U.S. Census Bureau.
[4]Less than ½ unit.
[5]Derived from the monthly averages of the consumer buying price in Pittsburgh, PA, as published in American Metal Market. The price represents Type 304 solids and clips containing 18% to 20% chromium and 8% to 12% nickel.

TABLE 2
NICKEL RECOVERED FROM PURCHASED SCRAP
IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons of contained nickel)

	2016	2017
Kind of scrap:		
Aluminum-base	1,780	1,840
Copper-base	1,270	1,270
Ferrous-base[2]	114,000 r	116,000
Nickel-base	2,750	2,510
Total	120,000 r	122,000
Form of recovery:		
Aluminum-base alloys	1,780	1,840
Copper-base alloys	2,090	2,060
Ferrous alloys	115,000 r	117,000
Nickel-base alloys	1,380	1,020
Total	120,000 r	122,000

rRevised.
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Primarily stainless- and alloy-steel scrap consumed at steel mills and foundries.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM[1]

(Metric tons of contained nickel)

Form	2016	2017
Primary:		
Metal	81,900 r	86,600
Ferronickel	11,000 r	10,300
Oxide and oxide sinter[2]	188 r	207
Chemicals	W	W
Other	2,920 r	3,450
Total	96,000 r	101,000
Secondary, scrap[3]	120,000 r	122,000
Grand total	216,000 r	223,000

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4
REPORTED U.S. CONSUMPTION OF NICKEL, BY USE[1]

(Metric tons of contained nickel)

Use	2017								Grand total in 2016
	Primary								
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total	
Chemicals and chemical uses	W	--	--	W	W	1,550	--	1,550	1,750
Electroplating, sales to platers	7,350	--	--	W	--	7,350	--	7,350	7,370
Other nickel and nickel alloys	13,500	W	W	--	83	13,600	2,810	16,400	14,700
Steel:									
Stainless and heat resistant	29,400	10,300	W	--	166	39,900	116,000	155,000	153,000 r
Alloys, excludes stainless	6,780	30	--	--	W	6,810	W	6,810	5,380 r
Superalloys	26,000	W	--	--	W	26,000	W	26,000	24,400 r
Other[2]	3,530	W	207	W	2,480	6,090 [3]	3,640	9,730	9,260 r
Total	86,600	10,300	207	W	2,730	101,000 [3]	122,000	223,000	216,000 r

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by a symbol W.
[3]Includes data indicated by a symbol W not included elsewhere.

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES,
BY FORM, DECEMBER 31[1]

(Metric tons of contained nickel)

Form	2016	2017
Primary:		
Metal	5,720	5,860
Ferronickel	W	W
Oxide and oxide sinter	73	42
Chemicals	W	W
Other	580	645
Total	6,370	6,540
Secondary, scrap	8,690 r	8,160
Grand total	15,100 r	14,700

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS[1]

Class	2016		2017	
	Quantity (metric tons of contained nickel)	Value (thousands)	Quantity (metric tons of contained nickel)	Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	2,680	$26,800	1,250	$15,500
Ferronickel	123	3,400	15	435
Powder and flakes	1,650	53,100	1,460	52,500
Metallurgical-grade oxide[2]	2,010	27,000	3,170	22,700
Chemicals:				
Catalysts[3]	2,830	212,000	4,050	349,000
Salts[4]	992	11,400	1,040	13,000
Total	10,300	334,000	11,000	453,000
Secondary:				
Stainless-steel scrap	49,100 r	442,000	36,600	425,000
Waste and scrap[5]	14,600	99,300	14,900	120,000
Total	63,700	541,000	51,500	545,000
Grand total	74,000 r	875,000	62,500	998,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	424	11,500	609	14,100
Sheets, strip, foil	255	8,200	300	8,860
Tubes and pipes	67	3,350	54	1,280
Total	746	23,100	963	24,300
Alloyed, gross weight:				
Unwrought alloyed ingot	5,550	104,000	5,550	157,000
Bars, rods, profiles, wire	21,100 r	657,000	23,300	688,000
Sheets, strip, foil	10,500	301,000	12,800	330,000
Tubes and pipes	1,830	117,000	1,700	130,000
Other alloyed articles	2,450	343,000	2,200	339,000
Total	41,300	1,520,000	45,600	1,640,000

rRevised.
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Nickel content is assumed to be 77%.
[3]Typical catalyst is assumed to have a nickel content of 22%.
[4]Nickel contents are as follows: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts, assumed to be 22%.
[5]Waste and scrap content is assumed to be 50% nickel; stainless-steel scrap, 7.5%.

Source: U.S. Census Bureau.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS, BY COUNTRY OR LOCALITY[1]

(Metric tons of contained nickel)[2]

	2017									
Country or locality[3]	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[4]	Waste and scrap	Stainless-steel scrap	Chemicals	Total	Total in 2016	Wrought nickel in 2017[5]
Australia	1	5	--	8	269	1	(6)	285	375	--
Austria	--	--	--	--	25	99	--	124	80	(6)
Belgium	--	7	--	--	9	122	123	262	286	--
Brazil	30	63	--	--	(6)	(6)	87	182	301	--
Canada	47	138	--	2,710	11,000	9,510	1,190	24,600	26,300	(6)
China	45	202	--	8	109	6,500	693	7,560	11,700	2
Denmark	--	6	--	--	--	3	103	112	124	--
Finland	--	1	--	(6)	128	2	(6)	131	121	20
France	--	23	(6)	4	18	3	220	269	120	83
Germany	--	249	(6)	4	101	54	55	462	441	--
Hong Kong	--	12	1	(6)	232	1,020	(6)	1,270	1,110	(6)
India	--	14	11	(6)	745	3,320	229	4,310	6,080	1
Indonesia	--	--	--	38	--	239	13	290	41	--
Japan	3	103	--	--	445	690	121	1,360	2,260	11
Korea, Republic of	--	90	--	(6)	20	601	172	882	2,210	26
Kuwait	--	--	--	--	--	--	671	671	26	6
Malaysia	(6)	--	--	(6)	1	127	54	183	196	(6)
Mexico	397	91	(6)	3	27	1,910	220	2,640	2,050	9
Netherlands	10	18	--	(6)	202	125	333	688	964 r	--
Pakistan	--	1	--	--	202	4,320	3	4,530	4,820	(6)
Singapore	1	166	1	1	60	44	38	310	273	--
Sweden	--	3	--	--	779	140	1	923	1,590	12
Taiwan	11	20	--	--	7	7,410	120	7,560	9,630	(6)
Thailand	--	56	(6)	--	--	40	31	127	163	--
Turkey	--	24	--	(6)	--	23	96	143	32	(6)
United Arab Emirates	660	8	--	--	--	35	26	729	94	--
United Kingdom	--	44	--	366	513	70	15	1,010	1,550	8
Vietnam	1	6	--	--	--	75	39	121	116	--
Other[7]	39	112	2	32	44	148	436	811	916 r	567
Total	1,250	1,460	15	3,170	14,900	36,600	5,090	62,500	74,000 r	746

rRevised. -- Zero.

[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless-steel scrap, 7.5%. The "Chemicals" category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.

[3]Countries and (or) localities listed were the leading export recipients in 2017 in terms of quantity (contained weight).

[4]Chemical-grade oxide is included in the "Chemicals" category.

[5]Not included in "2017, Total."

[6]Less than ½ unit.

[7]Includes 81 countries and (or) localities with less than 100 metric tons total in 2017.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS[1]

Class	2016 Quantity (metric tons of contained nickel)	2016 Value (thousands)	2017 Quantity (metric tons of contained nickel)	2017 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	95,000 r	$940,000	118,000	$1,240,000
Ferronickel	8,090	102,000	22,700	243,000
Powder and flakes	4,730 r	77,100 r	5,430	92,100
Metallurgical-grade oxide[2]	407	8,170	225	5,900
Chemicals:				
Catalysts[3]	1,500	88,300	1,590	82,900
Salts[4]	1,330	17,200	1,660	24,100
Total	111,000	1,230,000	150,000	1,690,000
Secondary:				
Stainless-steel scrap	19,700	182,000	21,200	280,000
Waste and scrap[5]	12,600	143,000	16,900	214,000
Total	32,300	325,000	38,100	494,000
Grand total	143,000	1,560,000	188,000	2,180,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	300	10,000	311	10,100
Sheets, strip, foil	430	8,940	562	11,200
Tubes and pipes	44	901	103	2,570
Total	774	19,900	977	23,800
Alloyed, gross weight:				
Unwrought alloyed ingot	8,110	115,000	7,480	66,500
Bars, rods, profiles, wire	10,400	211,000 r	14,300	305,000
Sheets, strip, foil	3,540	70,500	3,980	78,800
Tubes and pipes	1,330	85,400 r	2,330	105,000
Other alloyed articles	3,410	237,000	4,150	232,000
Total	26,700	719,000 r	32,200	788,000

rRevised.
[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Nickel content from Australia, 90%; elsewhere, 77%.
[3]Typical catalyst is assumed to have a nickel content of 22%.
[4]Nickel contents are as follows: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts, assumed to be 22%. Excludes nickel carbonate.
[5]Waste and scrap is assumed to 50% nickel; stainless-steel scrap, 7.5%.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY OR LOCALITY[1]

(Metric tons of contained nickel)[2]

	2017									
Country or locality[3]	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[4]	Waste and scrap	Stainless-steel scrap	Chemicals	Total	Total in 2016	Wrought nickel in 2017[5]
Australia	8,620	342	--	--	193	(6)	(6)	9,160	2,860	--
Belgium	--	90	--	--	21	2	317	431	297	2
Brazil	518	--	5,850	--	93	321	11	6,790	5,500	--
Canada	54,000	3,750	--	--	4,140	10,600	74	72,700	70,000	(6)
China	382	61	399	219	1,120	10	32	2,230	1,390	14
Colombia	--	--	884	--	4	47	--	935	1,680	--
Denmark	--	--	--	--	--	--	311	311	86	2
Dominican Republic	--	--	4,190	--	23	7	--	4,220	155	--
Finland	14,100	66	--	--	--	--	158	14,300	8,410	--
France	(6)	15	(6)	--	1,100	3	280	1,400	1,220	129
Germany	--	67	--	--	1,110	377	291	1,840	1,660 r	626
Guatemala	--	--	5,500	--	--	7	--	5,510	222	--
India	--	(6)	--	--	39	4	545	588	316	37
Israel	--	1	--	--	153	22	--	175	79	--
Italy	--	(6)	--	--	232	--	9	241	180	(6)
Japan	3,500	83	--	(6)	1,260	52	493	5,390	4,710	51
Korea, Republic of	--	--	--	1	284	2	71	357	521	--
Madagascar	3,420	--	--	--	--	--	--	3,420	2,920	--
Mexico	8	--	--	1	1,550	9,210	1	10,800	8,700	(6)
Netherlands	--	17	200	--	67	3	220	507	1,410	1
New Caledonia	--	--	5,700	--	--	--	--	5,700	2,850	--
Norway	18,300	--	--	--	39	(6)	--	18,300	11,900	--
Philippines	--	--	--	--	10	--	231	241	145	--
Russia	11,900	45	--	--	632	161	(6)	12,700	9,630	12
Singapore	--	--	--	--	453	(6)	2	455	220	(6)
South Africa	2,670	378	--	1	--	--	1	3,050	2,150	--
Spain	--	--	--	--	414	1	--	414	56	--
Switzerland	--	38	--	--	186	--	--	224	153	(6)
Taiwan	--	--	--	--	171	58	102	331	193	(6)
Turkey	--	--	--	--	252	--	--	252	266	--
United Kingdom	706	454	9	4	3,020	21	52	4,270	3,210	38
Other[7]	2	15	--	(6)	313	230	47	608	338 r	65
Total	118,000	5,430	22,700	225	16,900	21,200	3,250	188,000	143,000	977

rRevised. -- Zero.

[1]Table includes data available through January 14, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The "Chemicals" category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel; stainless-steel scrap, 7.5% nickel.

[3]Countries and (or) localities listed were the leading exporters in the United States in 2017 in terms of quantity (contained weight).

[4]Primarily oxide, rondelles, and sinter.

[5]Not included in "2017, Total."

[6]Less than ½ unit.

[7]Includes 43 countries and (or) localities with less than 100 metric tons total in 2017.

Source: U.S. Census Bureau.

TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, contained nickel)

Country or locality[3]	2013	2014	2015	2016	2017
Albania, laterite ore[e]	2,100	4,900	6,500	4,000 [r]	2,300
Australia, undifferentiated or other	290,986	266,181	225,227	203,135 [r]	178,853
Botswana, sulfide ore, matte produced	22,848	14,958	16,789	14,273 [r]	--
Brazil, undifferentiated or other	108,000	102,000	94,800 [r]	86,400 [r]	78,600 [e]
Burma, laterite ore	6,100	21,000	26,400	22,800	22,800
Canada, sulfide ore, concentrate	227,743	228,867	225,351 [r]	230,210 [r]	214,304
China, undifferentiated or other	93,200	101,100	101,400	98,100 [r, e]	103,000 [e]
Colombia, laterite ore:[4]					
Calculated	74,400	62,200	NA	NA	NA
Dry	NA	NA	40,513 [r]	41,082 [r]	45,510
Cuba, laterite ore	55,600 [r]	51,600 [r]	53,800 [r]	51,600	52,800
Dominican Republic, laterite ore	15,825	--	4,000 [e]	19,900 [e]	28,300 [e]
Finland, undifferentiated or other	19,440	18,730	9,383	20,654	34,641
Greece, laterite ore	19,100	21,405	19,610	19,431	19,073
Guatemala, laterite ore	10,200	46,800	56,400	45,900	53,700
Indonesia, laterite ore	834,200	177,100	129,600	198,900	345,000
Kosovo, laterite ore[e]	7,610 [r]	6,720 [r]	7,420 [r]	4,270 [r]	7,120
Madagascar, laterite ore, nickel cobalt sulfide[e]	29,000	43,000	55,000	49,000	41,700
Morocco, undifferentiated, nickel hydroxide	160	220 [r]	203 [r]	188 [r]	200 [e]
New Caledonia, laterite ore	164,406	175,174	193,199	204,207	215,382
Norway, undifferentiated or other	335	400	285	220	206
Papua New Guinea, laterite ore, nickel cobalt hydroxide[5]	11,369	20,987	25,582	22,269	34,666
Philippines, laterite ore	313,050 [r]	443,909	466,754 [r]	348,877 [r]	365,981
Russia:					
Laterite ore	10,400 [e]	11,200 [e]	7,400	7,000 [e]	1,800 [e]
Sulfide ore, concentrate	219,273 [r]	223,224 [r]	222,440 [r]	201,107 [r]	212,417
South Africa, sulfide ore, concentrate	51,208	54,956	56,689	48,994	48,383
Spain, sulfide ore, concentrate	7,574	8,631	7,213	--	--
Turkey, laterite ore	1,200	3,500 [r]	9,900 [r]	10,200	18,000
United States, sulfide ore, concentrate	--	4,300	27,200	24,100	22,100
Venezuela, laterite ore	-- [e]	5,000	4,800	--	--
Vietnam, sulfide ore, concentrate	1,166	6,854	8,607	4,272	--
Zimbabwe, sulfide ore, concentrate	12,962	16,633	16,109	17,743	16,617
Total	2,610,000 [r]	2,140,000 [r]	2,120,000 [r]	2,000,000 [r]	2,160,000
Of which:					
Laterite ore	1,550,000 [r]	1,090,000 [r]	1,110,000 [r]	1,050,000	1,250,000
Sulfide ore	543,000 [r]	558,000 [r]	580,000 [r]	541,000 [r]	514,000
Undifferentiated or other	512,000	489,000 [r]	431,000 [r]	409,000 [r]	396,000

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

[1]Table includes data available through November 7, 2018. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output, and this was noted.

[3]In addition to the countries and (or) localities listed, North Korea may have produced nickel, but available information was inadequate to make reliable estimates of output.

[4]Prior to 2013, mine production was as reported by the International Nickel Study Group. From 2015 onward, mine production data were estimated using data from South 32 Company.

[5]Often called mixed hydroxide product or MHP by industry.

TABLE 11
NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, contained nickel)

Country or locality	2013	2014	2015	2016	2017
Matte:					
Australia	70,111	61,541	44,268	38,247	36,812
Botswana	22,848	14,958	16,789	14,273	--
Brazil[3]	11,641	--	--	--	--
Canada[e, 4]	76,000 r	77,100 r	88,300 r	90,800 r	65,200
Finland	8,662	8,363	17,000	25,000	31,000
Indonesia[5]	75,802	78,726	81,177	77,581	76,807
New Caledonia	13,279	8,241 r	6,761 r	4,287	--
Russia[e, 6]	--	--	812 r	16,900 r	42,700
South Africa	5,800	7,700	400	--	--
Zimbabwe[7]	3,909	4,830	3,887	5,434	5,111
Total	288,000 r	261,000 r	259,000 r	273,000 r	258,000
Other:					
Cuba:[e]					
Ammoniacal liquor precipitate and unspecified	1,100 r	620 r	690 r	640 r	690
Nickel-cobalt sulfide[8]	36,000 r	36,700 r	36,700 r	34,800 r	35,200
New Caledonia, nickel-cobalt hydroxide[9]	7,557	12,464	9,686 r	7,269 r	6,525
Papua New Guinea, nickel-cobalt hydroxide[9]	11,369	20,987	25,582	22,269	34,666
Philippines, nickel-cobalt sulfide[8]	26,021	50,647	51,733 r	48,371 r	50,553
Turkey, nickel-cobalt hydroxide[9]	--	--	--	1,790	4,000
Total	82,000 r	121,000 r	124,000 r	115,000 r	132,000
Grand total	370,000 r	383,000 r	384,000 r	388,000 r	389,000

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through March 5, 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]Data represent nickel content of matte and other intermediate materials produced.
[3]Represents the output of the Fortaleza smelter.
[4]Nickel content of matte and metallurgical-grade nickel oxide as reported by the Global Trade Atlas reported using Harmonized System number 7501. According to the International Nickel Study Group, the nickel content of matte was 50% and the nickel content of metallurgical-grade oxide was 75.2%.
[5]Represents the nickel output of the Soroako smelter. The Soroako matte was is shipped to Japan for further processing and contains on average 78% nickel.
[6]Nickel content of matte, primarily exported to Finland, as reported by the Global Trade Atlas reported using Harmonized System number 7501, with an estimated 40% nickel content.
[7]Zimplats matte shipped to the Impala Refinery at Springs, South Africa.
[8]Often called mixed sulfide product or MSP by industry.
[9]Often called mixed hydroxide product or MHP by industry.

TABLE 12
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY OR LOCALITY AND PRODUCT[1, 2]

(Metric tons, contained nickel)

Country or locality and product	2013	2014	2015	2016	2017
Australia:					
Metal	132,753	129,862	132,074	117,920	103,900
Unspecified[3]	8,499	7,901	20,904	2,600	--
Total	141,252	137,763	152,978	120,520	103,900
Austria, ferronickel	1,000	1,000	1,000	1,000	1,000
Brazil:					
Ferronickel	34,501	37,200 r, e	54,700	68,600	68,500
Metal	19,823	21,000	21,900 e	--	--
Total	54,324	58,200 r	76,600	68,600	68,500
Burma, ferronickel[e, 4]	1,200 r	15,000 r	16,000	8,700 r	8,700
Canada, unspecified	152,728	149,486	149,716 r	158,299 r	163,200
China:[5]					
Chemicals	9,000	20,000	18,891	29,100 r	39,900
Ferronickel, nickel pig iron	480,000	471,500	385,035	374,745 r	411,462
Metal	227,000	247,000	236,700	221,700 r	205,000 e
Total	716,000	738,500	640,626	625,545 r	656,000
Colombia, ferronickel	49,320	41,221	36,671	37,092 r	40,600
Cuba, oxide sinter, including oxides[6]	16,616	13,252 r	14,667 r	15,006 r	15,000 e
Dominican Republic, ferronickel	9,400	--	--	9,913	15,632
Finland:					
Chemicals	4,400	5,964 r	7,129 r	8,048 r	8,358
Metal	39,851 r	36,639 r	36,350 r	45,606 r	51,342
Total	44,251 r	42,603 r	43,479 r	53,654 r	59,700
France, unspecified[7]	12,121 r	8,404 r	6,533 r	4,639 r	2,329
Greece, ferronickel	16,890 r	18,481	17,113 r	17,071 r	16,781
Guatemala, ferronickel	--	5,040	10,826	8,688	12,416
Indonesia:					
Ferronickel	18,249	16,851	17,211	20,293	21,762
Ferronickel, nickel pig iron	--	--	27,200 e	75,865 e	48,900 e
Total	18,249	16,851	44,400 e	96,200 e	70,700 e
Japan:					
Chemicals	2,191 r	5,673	10,045	11,153 r	16,773
Ferronickel	80,554 r	70,100 e	71,200 e	70,300 e	65,300 e
Metal	46,405	56,129	64,068	63,132 r	61,377
Oxide sinter[e]	48,900	45,900	47,500	46,900	43,600
Total	178,000	178,000	193,000	191,000 r	187,000 e
Korea, Republic of, ferronickel[8]	25,376	22,799	39,005	45,600	47,400
Kosovo, ferronickel	6,999 r	7,746 r	11,301 r	2,540 r	7,700
Macedonia, ferronickel	20,001	18,054	17,699	10,603	7,175
Madagascar, metal	25,148	37,053	47,271	42,105	35,474
Morocco, chemicals, nickel hydroxide	175 r	200 r, e	203 r	188 r	200 e
New Caledonia:					
Ferronickel	40,459	54,683 r	56,486	67,518	73,219
Oxide sinter	7,911	7,366	21,044	28,465	30,875
Total	48,370	62,049 r	77,530	95,983	104,094
Norway, metal	91,017	90,500	91,220	92,700	86,500
Russia:					
Chemicals	2,700	2,700	2,900	2,400 e	--
Metal	241,800	234,700	231,200	188,700 r	157,396
Total	244,500 r	237,400 r	234,100 r	191,000 r	157,396
South Africa:					
Chemicals[e, 9]	5,000 r	3,500	5,300 r	4,700 r	4,900
Metal	33,200	34,100	42,000 r	42,200 r	43,200
Total	38,200 r	37,600	47,300 r	46,900	48,100
Ukraine, ferronickel[10]	21,200 r, e	18,600 r, e	18,000 r, e	18,100	15,300
United Kingdom, metal	42,400	39,100	38,804	45,194	38,900 e
Venezuela, ferronickel	--	5,000	4,000	--	--
Zimbabwe, metal[11]	2,845	2,915	617	--	--

See footnotes at end of table.

TABLE 12—Continued
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY OR LOCALITY AND PRODUCT[1, 2]

(Metric tons, contained nickel)

Country or locality and product	2013	2014	2015	2016	2017
Grand total	1,980,000	2,000,000	2,030,000 r	2,010,000 r	1,970,000
Of which:					
Chemicals	23,500 r	38,000 r	44,500 r	55,600 r	70,100
Ferronickel	805,000	803,000 r	783,000 r	837,000 r	862,000
Metal	902,000 r	929,000 r	942,000 r	859,000 r	783,000
Oxide sinter	73,400	66,500	83,200 r	90,300 r	89,400
Unspecified	173,000 r	166,000 r	177,000 r	166,000 r	166,000

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through March 19, 2019. All data are reported unless otherwise noted. Grand totals and estimated data are rounded to three significant digits; may not add to totals shown.

[2]In addition to the countries and (or) localities listed, North Korea was thought to have produced metallic nickel and (or) ferronickel, but information was inadequate to make reliable estimates of output levels. Several countries and (or) localities produced nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries and (or) localities that produced matte for export are listed in table 11.

[3]Products with a nickel content of less than 99%. Includes ferronickel, nickel oxides and oxide sinter and excludes intermediate nickel-cobalt sulfide matte, regulus, and speiss for further refining.

[4]Imports to other countries and (or) localities of ferronickel from Burma, assumed 26% nickel content.

[5]Preliminary figures for ferronickel and chemicals were derived from data published by Beijing Antaike Information Development Co. Ltd. Figures for electrolytic and other class I nickel are based on data provided by the China Nonferrous Metals Industry Association and the International Nickel Study Group. China also produced nickeliferous pig iron from laterite ores imported from Indonesia, New Caledonia, and the Philippines.

[6]Includes cobalt content of nickel oxide and oxide sinter.

[7]Includes metal and nickel chloride.

[8]Utility® Nickel production figures for the Republic of Korea and Taiwan were not included because the production was derived wholly from imported metallurgical-grade oxides and to include them would result in double counting.

[9]Primarily in the form of crystalline nickel sulfate.

[10]May include nickel in remelt alloys derived from scrap.

[11]Data represent production from matte imported from Botswana and nickel sulfate imported from South Africa.