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Nickel

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Reported nickel consumption (primary plus secondary) in the United States in 2018 decreased by 3% to 230,000 metric tons (t) compared with 238,000 t (revised) in 2017 (table 1). U.S. apparent consumption of primary nickel was 136,000 t or about 6% of the 2.33 million metric tons (Mt) of world consumption reported by the International Nickel Study Group (INSG). Stainless-steel production accounted for 40% of U.S. reported primary consumption of nickel compared to 66% globally, including the United States. This difference 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). In 2018, U.S. industry melted 123,000 t of nickel contained in scrap, a 7% decrease from 133,000 t (revised) in 2017 (table 2) (Nickel Institute, 2016, p. 14; International Nickel Study Group, 2020b, p. A–1).

In this chapter, primary nickel refers to a nickel product produced from the beneficiation and processing of mined ore that is ready for use in a downstream consuming industry. The form and composition of the primary product are typically a function of the mineralogy of the ore deposit and types of processing used. Unwrought nickel metal in all forms (for example, briquet, cathode or electrolytic, flake, pellet, powder, rondelles) in this chapter has a purity of greater than 99% and generally conforms to the INSG's definition of Class I nickel. Nickel oxide sinter and iron- and nickel-containing products, such as ferronickel and nickel pig iron (NPI), generally conform to the INSG's definition of Class II nickel (International Nickel Study Group, 2020b, p. iii). Specifications for nickel traded on the London Metal Exchange Ltd. (LME) require a purity of 99.8% (American Society for Testing and Materials International standards) or 99.9% (Chinese National Standards) (London Metal Exchange Ltd., undated). Nickel chemicals and salts often are produced at nickel refineries but in this chapter are differentiated from production of metal whenever feasible.

Legislation and Government Programs

U.S. coinage in the form of nickels, dimes, quarters, half dollars, and one-dollar coins contain nickel in the form of cupronickel or manganese-brass alloy. Total nickel consumption for coin production was 2,872 t in 2018, an 11% decrease compared with 2017 (U.S. Mint, undated a, b).

In March, in response to the U.S. Department of Commerce's (DOC's) investigation into the effect of aluminum and steel imports on the national security of the United States, using authority granted under section 232 of the Trade Expansion Act of 1962, the President ordered that a 25% ad valorem tariff be placed on steel imports, including stainless steel, from all countries except Canada and Mexico. As directed by the proclamation, the DOC subsequently established a process for companies to apply for an exclusion to the tariff if certain conditions were met, such as a particular product's lack of availability from domestic producers (Trump, 2018; U.S. Department of Commerce, 2018).

Throughout the year, modifications and changes were made to the list of countries subject to the tariff. For some countries, quotas were established in place of the additional duties and exemptions for certain products were granted. Many countries responded to the increased import duties by increasing the duties for imports of aluminum and steel articles of United States origin, including European Union countries, Canada, China, India, Japan, Mexico, Russia, and Turkey. As of December 2018, the additional import duty for steel articles imported into the United States remained at 25% for most countries of origin and was 50% for Turkey. The only countries that did not have the increased import duty for steel were Argentina, Brazil, and the Republic of Korea, all of which had import quotas in place, and Australia (U.S. Geological Survey, 2019, p. 7).

In March, Allegheny & Tsingshan Stainless was formed as a joint venture between Allegheny Technologies Inc. (ATI) (Pittsburgh, PA) and Shanghai STAL Precision Stainless Steel Company Ltd. (China) to produce 60-inch-wide stainless-steel sheets from stainless-steel slab imported from Indonesia. ATI entered into the agreement with the intent of improving capacity utilization, specifically by reopening its previously idled Direct Roll Anneal and Pickle operation in Midland, PA. Because imports from Indonesia were subject to the section 232 tariffs, ATI filed for an exclusion and still was awaiting a decision at yearend 2018 (Allegheny Technologies Inc., 2019, p. 26).

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 2018, the Eagle Mine produced 17,600 t of nickel in concentrate, a 20% decrease compared with 22,100 t in 2017, although 2018 production exceeded the company's production guidance for the year (Lundin Mining Corp., 2019b, 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's (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 2018. 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 transported on a dedicated rail spur from Humboldt Township to the Canadian National Railway line and then to smelters in Canada or to ports for shipment overseas. In 2018, trade statistics from the U.S. Census Bureau indicated that 51% of total United States nickel concentrate exports went to Canada and 47% to Finland.

In 2018, Lundin continued development of an access ramp to the Eagle East mine extension. The Eagle East project is located approximately 2 kilometers (km) east and 600 meters deeper than the Eagle deposit and is part of the same intrusive complex. The Eagle East project was to be developed using existing infrastructure and mining methods similar to those used at the Eagle Mine and the company was able to amend the Eagle Mine permit to include 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 2018 resource and reserve statement, the average nickel grade of Eagle East's probable reserves was 3.7%, approximately 57% higher than that of the original Eagle Mine. Total proven and probable reserves for the project, including the Eagle Mine and Eagle East, totaled 108,000 t of nickel, with Eagle East contributing 57,000 t (Lundin Mining Corp., 2019a, p. 32–39, 89; 2019b, p. 17).

Minnesota.—In June, PolyMet Mining Corp. (Canada) completed a land exchange with the U.S. Forest Service that gave the company control over both surface and mineral rights in and around the NorthMet copper, nickel, and platinum-group-metal (PGM) deposit. By yearend 2018, the company had received all necessary permits from the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency but was still awaiting the Record of Decision and wetlands permit, which was the last permit needed to begin development, from the U.S. Army Corps of Engineers. The project is located 10 km 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., 2019, p. 4).

Byproduct Smelter and Refinery Production.—Sibanye Gold Ltd., trading as Sibanye-Stillwater, 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 in crude oil. Gladieux first roasted and leached the spent catalysts to recover the molybdenum and vanadium. The nickel-and-alumina residue then was 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 107,000 t in 2018, a slight increase compared with 105,000 t (revised) in 2017 (table 1). The estimated value of reported primary nickel consumption was $1.40 billion, a 29% increase compared with that in 2017, which was primarily the result of a 26% increase in the annual average LME cash price. U.S. industry consumed 13,500 t of ferronickel in 2018, of which more than 99% was used in stainless, heat-resisting, or specialty alloy steels (table 4).

Stainless Steel and Low-Alloy Steels.—In 2018, stainless-steel producers accounted for 40% of reported primary nickel consumption, 69% of total nickel consumption, and 95% of nickel-containing scrap consumption in the United States. Alloy steels—other than stainless steel—accounted for 8% of U.S. primary nickel use (table 4). Production of raw stainless steel and heat-resisting steel in the United States increased slightly to 2.81 Mt. Production of nickel-bearing grades increased by 14% to 2.08 Mt compared with that in 2017 and accounted for 74% of total stainless-steel production (American Iron and Steel Institute, 2018, 2019). Leading domestic stainless-steel producers included AK Steel Holding Corp. (West Chester Township, OH), ATI, North American Stainless (Ghent, KY), and Outokumpu Stainless USA, Llc (Calvert, AL).

Superalloys and Related Nickel-Base Alloys.—Of the primary nickel consumed in the United States in 2018, approximately 39% was used to make high-performance superalloys and related nickel-base alloys, primarily for the aerospace, electric power, and petrochemical industries (table 4). Leading domestic producers of these products included ATI, Carpenter Technology Corp. (Philadelphia, PA), Haynes International Inc. (Kokomo, IN), Precision Castparts Corp. (Portland, OR), and Special Metals Corp. (New Hartford, NY).

Typical applications for nickel-base alloys and superalloys in the aerospace industry included 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 could withstand higher temperatures. In 2018, the company reported that sales of jet engine products increased by nearly

50% compared with sales in 2017 and began production at its newly completed nickel and superalloy powder manufacturing facility in North Carolina (Allegheny Technologies Inc., 2019, p. 22–23).

Batteries.—Nickel began to be more widely used as a battery material in the 1980s beginning with nickel-cadmium batteries. This trend was accelerated in the 1990s when Toyota Motor Corp. adopted nickel-metal-hydride batteries for use in the hybrid Prius (Nickel Institute, undated). However, batteries accounted for only a small percentage of nickel consumption in 2018, 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 7% of primary nickel consumption (table 4).

Nickel is used increasingly in the cathodes of many lithium-ion batteries. Two of the most common cathode formulations are lithium-nickel-cobalt-aluminum and lithium-nickel-cobalt-manganese (NCM). The Nickel Institute estimated that in 2016, 39% of lithium-ion batteries contained nickel, but expected that number 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, NCM 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 (Nickel Institute, 2018; Vale S.A., undated).

The USGS annual nickel consumption survey was sent to domestic consumers of primary nickel products. Although the United States was among the leading producers of lithium-ion batteries globally, the country 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.

Stocks

Global stocks of nickel metal held in LME-approved warehouses decreased by 44% to 206,400 t at yearend 2018 compared with stocks at yearend 2017. Most of the decrease (78%) was in the form of bagged briquets. 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, 2018).

Data collected by the INSG indicated that in December 2018 world nickel producers held 86,200 t of primary nickel stocks, a 5% increase compared with stocks at yearend 2017 (International Nickel Study Group, 2020b, p. A–1). At yearend 2018, U.S. consumer stocks of primary nickel totaled 6,780 t, a 4% increase compared with yearend 2017 (tables 1, 5).

Prices

According to Platts Metals Week, the LME average annual cash price for nickel was $13,114 per metric ton, a 26% increase compared with $10,403 per metric ton in 2017 (table 1). However, the December 2018 average monthly price was 5% lower than the December 2017 average monthly price. The 2018 average monthly price peaked in June at $15,107 per metric ton but declined throughout the second half of the year.

World Review

In 2018, global nickel mine production increased by 10% to 2.40 Mt (table 10). Production from laterite deposits increased by 20% and accounted for 62% of total mine production compared with 56% in 2017. Most of the increase was attributed to Indonesia, owing to an easing of its export ban on direct shipping ore and rampup of NPI operations. Production from sulfide and other deposit types decreased by 3%. Global primary production increased slightly to 2.04 Mt compared with 1.99 Mt (revised) in 2017 (table 12). Production of nickel chemicals and ferronickel, including NPI, each increased by 9%. In 2018, production of ferronickel and NPI exceeded production of nickel metal and other unspecified refinery products.

According to the INSG, world consumption of primary nickel increased by 7% to 2.33 Mt (International Nickel Study Group, 2020b, p. A–1). Stainless steel accounted for 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 50.7 Mt in 2018, a 6% increase compared with 2017. China was the leading producer of stainless steel, accounting for 53% of world output, as well as the leading nickel consumer (International Stainless Steel Forum, 2020, p. 7, 12). On a global basis, nonferrous alloys accounted for 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).

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 or localities that mined both sulfide and laterite ores. Mine production decreased for the fourth consecutive year, to 170,312 t, as several mines and processing facilities remained on care-and-maintenance status (table 10). However, exploration expenditures continued to be high and increased mine production was expected in coming years from new or reactivated mining operations. Australia ranked fifth in primary nickel output in 2018 and during the previous 2 years produced only refined metal. Primary metal production increased by 5% to 113,500 t (table 12). All of Australia's active mines and processing facilities were located in Western Australia (Department of Industry, Innovation, and Science, 2018, p. 85–88).

BHP Billiton Ltd.'s Nickel West Kwinana refinery, which produced high-purity nickel briquets and powder with a nickel content of 99.8%, continued to increase the percentage of sales to battery precursor manufacturers. 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 cathodes. Streamlining projects underway were expected to increase Kwinana's capacity to 90,000 metric tons per year (t/yr). The company began production of nickel sulfate from a pilot plant in Perth and received all regulatory approvals to begin construction of a full-scale nickel sulfate plant at the Kwinana refinery with a stage 1 capacity of 100,000 t/yr of nickel sulfate (BHP Billiton Ltd., 2018, p. 58; Haegel, 2018a, p. 6–11; 2018b, p. 14–16).

Brazil.—In 2018, Brazil's mine production decreased by 3% to 74,400 t (table 10) and total plant production was 65,200 t, a 5% decrease from that in 2017 (table 12). 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 2018, 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., 2019, p. 52).

Vale's Onça Puma mining operation remained idled in 2018. In 2017, a Federal court ordered mining operations stopped until reparations were made to the indigenous community after determining that the company was responsible for metal contamination of the Catete River near the operation. Vale appealed the ruling, asserting that the metals were naturally occurring and that there was no evidence of harm to human health. Operations at the smelter apparently were unaffected by the court order as Vale reported ferronickel production of 22,900 t in 2018, a 7% decrease compared with that in 2017 (Vale S.A., 2019, p. 52–54, 157).

Canada.—Globally, Canada ranked fifth in nickel mine production and fourth in plant production. Mine production was 175,761 t, a 15% decrease compared with 206,354 t (revised) in 2017 (table 10). Plant production decreased by 14% to 133,200 t (table 12). Four Provinces had active nickel mines in 2018—Manitoba, Newfoundland and Labrador, Ontario, and Quebec.

Owing to increased capital costs associated with increasingly stringent sulfur dioxide emissions standards, Vale Canada Ltd. permanently ended smelting and refining operations when it shut down the second furnace at its Thompson, Manitoba, refinery. The company was expected to continue to produce concentrate from sulfide ores extracted from the Birchtree Mine and the Thompson Mine, which would be shipped to Sudbury for processing (Vale S.A., 2019, p. 50).

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 (often called mixed hydroxide product or MHP), and nickel-cobalt sulfide (often called mixed sulfide product or MSP) to supply its primary production. According to INSG data, most of China's nickel mines were sulfide mines, with reserve grades typically averaging less than 1% nickel (International Nickel Study Group, 2020a, p. B–23—B–29).

In 2018, China's total primary production was 716,000 t, an increase of 9% compared with that in 2017, and which accounted for 35% of world primary nickel production (table 12). Production of chemicals and NPI increased, by 13% and 16%, respectively, and production of metal decreased by 5%. Imports of nickel ore and concentrate were 47.0 Mt (gross weight) in 2018, an increase of 34% compared with those in 2017. Imports from the Philippines accounted for 64% of ore and concentrate imports in 2018 compared with 83% in 2017 and imports from Indonesia nearly quadrupled, accounting for 32% of imports in 2018 (International Nickel Study Group, 2020b, p. B–13).

According to INSG data (International Nickel Study Group, 2020b, p. A–6, B–14—B–15), China was the world's leading consumer of nickel. Consumption was 1.20 Mt of primary nickel, a slight increase compared with that in 2017, accounting for 52% of world consumption in 2018. China's imports of unwrought, unalloyed nickel (Harmonized Schedule number 7502.10) were 212,000 t, a decrease of 10% compared with those in 2017. Imports from Russia accounted for 39% of China's imports of unwrought, unalloyed nickel; Australia, 33%; and Canada, 11%. Ferronickel imports (gross weight), which likely included NPI and which had increased in each of the previous 4 years, decreased by 32%. Indonesia accounted for 64% of China's ferronickel imports.

Finland.—Terrafame Ltd. [Finnish Minerals Group Ltd. (formerly Terrafame Group Ltd., Government of Finland), Trafigura Ventures V B.V., Galena Private Equity Resources Investment 2 L.P., Galena Private Equity Resources Investment 3 L.P. funds, and Sampo plc] stabilized operations at the polymetallic Sotkamo Mine and bioheap-leaching operation in central Finland. The operation produced 27,377 t of nickel in MSP, which was close to the initial design capacity of 30,000 t/yr. More than one-half of the production was sold for the manufacture of battery materials through an offtake agreement with Trafigura. In October, the company approved plans to construct a plant to produce separate nickel and cobalt sulfates for use in the manufacture of battery cathode precursors. The company continued development of detailed engineering designs and nearly completed earthwork construction by yearend 2018 (Terrafame Ltd., 2019, p. 3, 10–11, 14–15, 68).

PJSC MMC Norilsk Nickel's (Nornickel's) Harjavalta refinery used sulfuric-acid leaching to produce nickel metal in the form of briquets, cathodes, nickel salts, and powder. Harjavalta's production of nickel was 60,765 t, a slight increase compared with that in 2017. Of that total, 50% of the nickel was produced in briquets, 27% in cathode, 17% in nickel salts, and 6% in powder. Nornickel continued to reduce processing of third-party feed material and, in 2018, 98% of the feed was supplied by its mines in Russia. In October, Nornickel and BASF SE finalized an agreement under which Norilsk would supply cobalt and nickel from Harjavalta to BASF for the production of lithium-ion battery cathode materials at a plant to be built adjacent to the Harjavalta refinery (PJSC MMC Norilsk Nickel, 2019, p. 86–87, 92, 275).

Indonesia.—In 2018, Indonesia again became the leading global producer of mined nickel. The country's production

had been reduced since 2014 owing to its enforcement of a ban on direct shipping ore which was intended to stimulate development of domestic processing facilities. Mine production in 2018 was 606,000 t, a 71% increase compared with that in 2017 (table 10), but still less than the 834,000 t produced in 2013. Increased production was primarily a result of the development and commissioning of NPI smelters in the country and the easing of export restrictions on unprocessed ore beginning in January 2017. 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 (Home, 2017).

Primary production was 98,200 t, a slight increase compared with that in 2017 (table 12). Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk (Antam) produced 24,868 t of ferronickel. The balance of primary production was from NPI smelters. PT Vale Indonesia Tbk's smelter produced matte that was exported primarily to Japan for further refining (table 11). A number of companies were exploring the possibility of building high-pressure acid-leaching (HPAL) plants to produce nickel-cobalt intermediates and (or) battery-grade nickel and cobalt salts from laterite ores. PT Halmahera Persada Lygend's project on Obi Island began construction in early 2018. The project was expected to produce 240,000 t/yr (gross weight) of MHP, equivalent to approximately 37,000 t/yr of nickel and 5,000 t/yr of cobalt. Sumitomo Metal Mining Co., Ltd. (Japan) and Vale were working on a feasibility study to build an HPAL plant in southeast Sulawesi with a capacity to produce 40,000 t/yr of MSP. Other projects were reportedly being evaluated in central Sulawesi and Weda Bay (Ferro-alloys.com, 2018; Shah, 2018; Sumitomo Metal Mining Co., Ltd., 2019, p. 46).

Japan.—Japan ranked second in terms of primary nickel production but all feed material was imported owing to a lack of nickel mines. Primary production in 2018 was essentially unchanged at 187,000 t compared with that in 2017 (table 12). Japan produced 68,200 t of ferronickel, 57,517 t of metal, 45,438 t of oxide sinter, and 15,624 t of nickel chemicals.

New Caledonia.—New Caledonia ranked fourth in nickel mine production and sixth in primary production. Mine production was 216,225 t, essentially unchanged compared with that in 2017 (table 10). Total primary production was 107,914 t, an increase of 4% compared with that in 2017, of which 82,114 t was in the form of ferronickel and 25,800 t was nickel oxide sinter (table 12). New Caledonia also produced MHP, which was exported for further processing (table 11).

Philippines.—The Philippines ranked second in mine production, with 344,915 t, a slight increase compared with that in 2017 (table 10). Operations at 10 mines remained idled throughout 2018 owing to the Department of Environment and Natural Resources' ongoing audit to determine the adequacy of each operation's environmental protection measures (Mines and Geosciences Bureau, 2019).

In 2018, the Government drafted rules limiting the area that an operation could actively mine at any given time. The intent of the new regulations was to compel mining companies to continuously reclaim and reforest previously mined areas. Mining operations without processing plants would be limited to between 50 and 100 hectares depending on mine capacity. Operations with processing plants would be allowed a maximum of 162 hectares (Serapio and dela Cruz, 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 Corp. (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 Corp. (Sumitomo, Mitsui, and Nickel Asia Corp., listed in order of share)—operated HPAL plants that produced MSP that was shipped to Japan for refining (table 11).

Russia.—Russia ranked third in nickel mine and primary production in 2018. Mine production was 272,000 t, a 3% decrease compared with 266,000 t (revised) in 2017 (table 10). Ufaleynikel's (Koks Industrial Metallurgical Holding Co.) mines in the Sverlosvskaya Oblast halted production in 2017, so the country's mine production was primarily from Nornickel's sulfide mines in the Kola Peninsula and the Taymyr Peninsula. Nornickel's primary production was 158,005 t of carbonyl and electrolytic nickel, essentially unchanged compared with that in 2017. In 2018, Nornickel continued to implement upgrades to improve ore throughput and nickel recovery at the Polar Division's Norilsk and Talnakh concentrators and to increase tankhouse capacity at the Kola Division's Severonickel plant with the goal of increasing refined nickel capacity from 120,000 t/yr to 145,000 t/yr. Nornickel also was implementing chlorine-leaching to attain higher purity electrolytic nickel (PJSC MMC Norilsk Nickel, 2019, p. 33–35).

Turkey.—Meta Nikel Kobalt Madencilik Sanayi ve Ticaret A.Ş. (Vestel Elektronik Sanayi ve Ticaret A.Ş. and Zorlu Holding A.Ş.) continued to ramp up production, optimize operations, and increase capacity at its mine and processing plant in Gordes, Manisa Province. The operation used HPAL to produce MHP from laterite ores. In 2018, the operation produced 5,001 t of nickel in MHP, a 25% increase compared with that in 2017 (table 11). In February, Zorlu Holding signed an agreement with GSR Capital (China). GSR Capital would contribute $4.5 billion to build fully integrated lithium-ion battery operations in the country in exchange for 50% interest in Meta Nikel Kobalt and Vestel. According to the agreement, Meta Nikel Kobalt would quadruple existing MHP capacity to 40,000 t/yr, establish a sulfuric acid production plant at Gordes, and construct a plant to produce battery-grade nickel sulfate and cobalt sulfate at the company's site in Eskişehir. Vestel would construct a 25-gigawatthour-per-year plant to manufacture batteries for the electric vehicle and stationary energy storage markets using materials produced by Meta Nikel Kobalt (Zorlu Holding A.Ş., 2018, 2019, p. 152–153).

Outlook

From 2008 to 2018, global nickel consumption had a compound annual growth rate of 6% (International Nickel Study Group, 2020b, 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 6%, climbing from 1 Mt in 1950 to 50.7 Mt in 2018. Chromium-nickel grades (300 series)

constitute more than 50% of stainless-steel production (International Stainless Steel Forum, 2020, p. 3, 7, 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 Institute, 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, for both 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. Conversely, production of nickel metal has been decreasing since 2015 (table 12).

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TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons, nickel content, unless otherwise specified)

		2014	2015	2016	2017	2018
United States:						
Production, concentrate		4,300	27,200	24,100	22,100	17,600
Secondary recovery from purchased scrap:						
From ferrous scrap		118,000 r	110,000 r	125,000 r	127,000 r	117,000
From nonferrous scrap		9,010 r	5,590 r	5,790	5,740 r	5,690
Shipments of purchased scrap[2]		144,000 r	141,000 r	162,000 r	146,000 r	145,000
Exports:						
Ores and concentrates[3]		3,320	25,400	22,400	20,000	18,000
Primary		10,400	9,600 r	10,300	11,000	9,780
Secondary		56,300	51,900	63,700	51,500	67,200
Imports for consumption:						
Ores and concentrates[3]		92	24	(4)	64	3
Primary		156,000	130,000	111,000	150,000	144,000
Secondary		39,000	27,100	32,300	38,100	45,100
Consumption:						
Reported:						
Primary		112,000 r	107,000 r	97,800 r	105,000 r	107,000
Secondary, purchased scrap		127,000 r	116,000 r	131,000 r	133,000 r	123,000
Total		239,000 r	223,000 r	229,000 r	238,000 r	230,000
Apparent, primary		149,000	118,000	104,000	140,000	136,000
Apparent primary plus reported secondary		276,000 r	234,000 r	235,000 r	273,000 r	259,000
Stocks, yearend:						
London Metal Exchange Ltd., U.S. warehouses		1,560	4,210	5,230	3,780	2,270
Consumer, primary		10,800 r	10,600	6,370	6,550 r	6,780
Consumer, secondary		12,100	8,570	8,690	8,040 r	9,570
Total		24,500 r	23,400	20,300	18,400 r	18,600
Price, cash, London Metal Exchange:						
Average annual	dollars per metric ton	16,865	11,831	9,594	10,403	13,114
Average annual	dollars per pound	7.650	5.367	4.352	4.719	5.948
Price, Type 304 stainless-steel scrap, gross weight:[5]						
Average annual	dollars per metric ton	1,714	1,240	1,075	1,304	1,403
Average annual	dollars per long ton	1,742	1,260	1,092	1,325	1,426
World, mine production		2,130,000 r	2,110,000 r	2,010,000 r	2,190,000 r	2,400,000

r Revised.

[1] Table includes data available through May 13, 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, nickel content)

	2017	2018
Kind of scrap:		
Aluminum-base	1,840	1,900
Copper-base	1,270	1,260
Ferrous-base[2]	127,000 r	117,000
Nickel-base	2,630 r	2,530
Total	133,000 r	123,000
Form of recovery:		
Aluminum-base alloys	1,840	1,900
Copper-base alloys	2,080 r	2,100
Ferrous-base alloys	128,000 r	118,000
Nickel-base alloys	1,020	902
Total	133,000 r	123,000

rRevised.
[1]Table includes data available through May 13, 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, nickel content)

Form	2017	2018
Primary:		
Metal	87,500 r	89,600
Ferronickel	13,600 r	13,500
Oxide and oxide sinter[2]	190 r	202
Chemicals	W	W
Other[3]	3,310 r	3,440
Total	105,000 r	107,000
Secondary, scrap[4]	133,000 r	123,000
Grand total	238,000 r	230,000

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Table includes data available through May 13, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Includes base master alloys and withheld data not included elsewhere.
[4]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, nickel content)

Use	2018								Grand total in 2017
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total	
Chemicals and chemical uses	W	--	--	W	--	W	--	W	W
Electroplating, sales to platers	7,240	--	--	W	--	7,240	--	7,240	7,350
Other nickel and nickel alloys	14,000	W	W	--	84	14,100	2,640	16,700	16,500 r
Steel:									
Stainless and heat resistant	29,000	13,500	W	--	131	42,600	117,000	159,000	169,000 r
Alloys, excludes stainless	8,480	32	--	--	W	8,510	W	8,510	6,810
Superalloys	27,300	W	--	--	W	27,300	W	27,300	27,300 r
Other[2]	3,620	W	202	W	2,500	7,040 [3]	3,840	10,900	10,600 r
Total	89,600	13,500	202	W	2,720	107,000 [3]	123,000	230,000	238,000 r

rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.
[1]Table includes data available through May 13, 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 withheld data.
[3]Includes withheld data not included elsewhere.

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

(Metric tons, nickel content)

Form	2017	2018
Primary:		
Metal	5,860	6,010
Ferronickel	W	W
Oxide and oxide sinter	42	43
Chemicals	W	W
Other	645	733
Total	6,550 r	6,780
Secondary, scrap	8,040 r	9,570
Grand total	14,600 r	16,300

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Table includes data available through May 13, 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	2017 Quantity (metric tons, nickel content)	2017 Value (thousands)	2018 Quantity (metric tons, nickel content)	2018 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	1,220 r	$15,200 r	1,460	$21,300
Ferronickel	15	435	14	437
Powder and flakes	1,460	52,500	1,570	62,100
Metallurgical-grade oxide[2]	3,170	22,700	956	16,000
Chemicals:				
Catalysts[3]	4,050	349,000	4,700	362,000
Salts[4]	1,040	13,000	1,090	17,300
Total	11,000	453,000	9,780	479,000
Secondary:[5]				
Stainless-steel scrap	36,500 r	424,000 r	49,000	323,000
Waste and scrap	15,000 r	121,000 r	18,300	157,000
Total	51,500	544,000 r	67,200	481,000
Grand total	62,400 r	997,000 r	77,000	960,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	609	14,100	922	26,200
Sheets, strip, foil	300	8,860	392	14,200
Tubes and pipes	54	1,280	37	1,850
Total	963	24,300	1,350	42,300
Alloyed, gross weight:				
Unwrought alloyed ingot	5,550	157,000	5,570	193,000
Bars, rods, profiles, wire	23,300	688,000	27,100	853,000
Sheets, strip, foil	12,800	330,000	15,400	413,000
Tubes and pipes	1,720 r	130,000	2,750	247,000
Other alloyed articles	2,200	339,000	2,730	604,000
Total	45,600	1,640,000	53,500	2,310,000

rRevised.

[1]Table includes data available through May 13, 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, nickel content)[2]

	2018									
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 in 2018	Total in 2017	Wrought nickel in 2018[5]
Australia	21	7	--	--	718	3	16	766	285	6
Austria	--	--	--	--	--	143	6	149	124	--
Bangladesh	--	(6)	--	--	--	151	--	151	24	--
Belgium	10	10	--	4	48	560	432	1,060	262	5
Brazil	83	55	--	(6)	--	502	86	727	182	3
Canada	137	189	--	566	14,200	19,600	1,180	35,900	24,500 r	38
China	27	202	--	2	--	3,290	647	4,160	7,560	114
Colombia	18	11	--	1	--	--	98	128	50	1
Denmark	--	18	--	--	--	3	159	179	112	(6)
Finland	--	--	--	--	--	71	47	118	131	--
France	(6)	4	--	3	--	2	113	122	269	16
Germany	(6)	321	--	5	9	64	93	492	462	57
Hong Kong	--	3	--	(6)	52	239	6	300	1,270	15
India	(6)	21	10	(6)	550	6,400	470	7,450	4,320 r	23
Indonesia	--	16	--	49	--	324	9	398	290	--
Japan	133	109	--	4	838	615	32	1,730	1,360	2
Korea, Republic of	--	84	(6)	2	33	603	168	890	882	78
Kuwait	--	--	--	--	--	--	259	259	671	--
Malaysia	--	--	--	(6)	--	497	44	541	183	8
Mexico	930	57	3	13	14	3,180	82	4,280	2,640	813
Netherlands	--	7	--	(6)	290	286	245	828	678 r	2
Pakistan	--	2	--	--	--	2,790	11	2,800	4,530	--
Saudi Arabia	--	4	--	--	--	--	132	136	45	1
Serbia	--	--	--	--	--	--	148	148	(6)	--
Singapore	1	199	(6)	(6)	8	8	74	292	310	21
Spain	--	1	--	--	86	25	1	113	58	(6)
Sweden	--	11	--	(6)	748	136	3	899	923	18
Taiwan	8	17	(6)	--	19	7,490	249	7,790	7,560	11
Thailand	--	90	(6)	--	--	211	90	392	127	7
United Kingdom	83	39	--	278	517	88	16	1,020	1,010	44
Vietnam	--	5	--	--	--	1,600	159	1,760	121	13
Other[7]	5	85	--	29	84	123	709	1,030	1,510 r	53
Total	1,460	1,570	14	956	18,300	49,000	5,790	77,000	62,400 r	1,350

rRevised. -- Zero.

[1]Table includes data available through May 13, 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% nickel; chlorides, 25% nickel; and sulfates, 22% nickel. Other salts and various catalysts are assumed to be 22% nickel.

[3]Countries and (or) localities listed were the leading export recipients in 2018 in terms of quantity (nickel content).

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

[5]Not included in "Total in 2018."

[6]Less than ½ unit.

[7]Includes 75 countries and (or) localities with less than 100 metric tons each in 2018.

Source: U.S. Census Bureau.

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

Class	2017 Quantity (metric tons, nickel content)	2017 Value (thousands)	2018 Quantity (metric tons, nickel content)	2018 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	118,000	$1,240,000	112,000	$1,490,000
Ferronickel	22,700	243,000	21,700	299,000
Powder and flakes	5,430	92,100	6,800	140,000
Metallurgical-grade oxide[2]	225	5,900	319	8,010
Chemicals:				
Catalysts[3]	1,590	82,900	1,780	102,000
Salts[4]	1,660	24,100	1,280	22,100
Total	150,000	1,690,000	144,000	2,060,000
Secondary:[5]				
Stainless-steel scrap	21,200	280,000	24,800	345,000
Waste and scrap	16,900	214,000	20,300	318,000
Total	38,100	494,000	45,100	663,000
Grand total	188,000	2,180,000	189,000	2,720,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	311	10,100	264	6,290
Sheets, strip, foil	562	11,200	508	10,700
Tubes and pipes	103	2,570	65	1,800
Total	977	23,800	837	18,800
Alloyed, gross weight:				
Unwrought alloyed ingot	7,480	66,500	6,640	70,300
Bars, rods, profiles, wire	14,300	306,000 r	14,400	365,000
Sheets, strip, foil	3,980	78,800	4,340	91,000
Tubes and pipes	2,320 r	104,000 r	2,520	118,000
Other alloyed articles	4,150	232,000	6,420	309,000
Total	32,300 r	787,000 r	34,300	954,000

rRevised.

[1]Table includes data available through May 13, 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 have 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, nickel content)[2]

	2018									
Country or locality[3]	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide	Waste and scrap	Stainless-steel scrap	Chemicals	Total in 2018	Total in 2017	Wrought nickel in 2018[4]
Australia	18,200	378	73	22	260	2	--	19,000	9,160	(5)
Belgium	--	226	--	--	22	2	347	596	431	--
Brazil	115	--	6,800	--	267	143	5	7,330	6,790	--
Canada	48,400	4,090	--	--	4,680	9,560	155	66,900	72,700	1
China	300	125	450	252	1,310	8	106	2,550	2,220 r	31
Colombia	--	--	775	--	12	29	--	816	935	--
Denmark	--	--	--	--	--	--	155	155	311	3
Dominican Republic	--	--	5,640	--	--	4	--	5,640	4,220	--
Finland	10,300	529	--	--	8	225	177	11,300	14,300	--
France	--	13	101	--	1,070	4	361	1,550	1,400	160
Germany	(5)	84	--	--	1,090	1	324	1,500	1,840	478
Guatemala	--	--	3,110	--	--	9	--	3,120	5,510	--
India	--	17	--	--	93	9	404	523	588	38
Indonesia	--	--	--	--	8	266	--	274	11	--
Italy	--	1	26	--	458	2	4	492	241	5
Japan	3,610	66	--	--	1,150	60	337	5,220	5,360 r	10
Korea, Republic of	--	(5)	--	9	318	5	32	365	357	(5)
Kuwait	--	--	--	--	--	--	108	108	--	--
Madagascar	1,860	--	--	--	--	--	--	1,860	3,420	--
Malaysia	703	--	--	--	--	15	--	718	10	1
Mexico	--	--	--	18	1,720	10,600	1	12,300	10,800	1
Netherlands	112	--	--	--	40	2,960	192	3,310	507	3
New Caledonia	--	--	3,720	--	--	--	--	3,720	5,700	--
North Macedonia	--	--	892	--	--	--	--	892	--	--
Norway	13,800	--	--	16	10	--	--	13,800	18,300	--
Philippines	--	--	--	--	17	--	117	134	241	--
Poland	--	--	--	--	74	--	30	103	83	--
Russia	9,280	53	--	--	1,070	596	--	11,000	12,700	--
Saudi Arabia	--	--	--	--	611	3	25	640	31	--
Singapore	--	1	--	--	608	--	--	609	455	--
South Africa	4,820	455	57	--	196	--	10	5,540	3,050	--
Spain	--	2	--	--	407	2	--	410	414	--
Switzerland	--	1	--	--	110	(5)	--	111	224	(5)
Taiwan	--	1	--	--	214	61	39	316	331	(5)
Turkey	--	--	--	--	236	--	--	236	252	--
United Kingdom	461	746	31	3	3,930	16	126	5,320	4,270	60
Other[6]	91	8	--	--	280	255	1	635	649 r	46
Total	112,000	6,800	21,700	319	20,300	24,800	3,050	189,000	188,000	837

rRevised. -- Zero.

[1]Table includes data available through May 13, 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% nickel; chlorides, 25% nickel; sulfates, 22% nickel. 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 import sources in 2018 in terms of quantity (nickel content).

[4]Not included in "Total in 2018."

[5]Less than ½ unit.

[6]Includes 43 countries and (or) localities with less than 100 metric tons each in 2018.

Source: U.S. Census Bureau.

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

(Metric tons, nickel content)

Country or locality[3]	2014	2015	2016	2017	2018
Albania, laterite ore[e]	4,900	6,500	3,950 r	2,320 r	1,800
Australia, undifferentiated or other	266,181	225,227	203,135	178,853	170,312
Botswana, sulfide ore, matte produced	14,958	16,789	14,273	--	--
Brazil, undifferentiated or other	102,000	94,800	86,400	76,800 r	74,400
Burma, laterite ore	21,000	23,000 r	20,000 r	20,000 r	21,000
Canada, sulfide ore, concentrate	218,233 r	225,351	230,210	206,354 r	175,761
China, undifferentiated or other	101,100	101,400	100,200 r	105,000 r, e	110,000 e
Colombia, laterite ore:[4]					
Calculated	62,200	NA	NA	NA	NA
Dry	NA	40,513	41,082	45,510	47,700
Cuba, laterite ore	51,600	53,800	51,600	52,800	51,000
Dominican Republic, laterite ore	--	4,000 e	19,900 e	28,300 e	34,700 e
Finland, undifferentiated or other	18,730	9,383	20,654	34,641	43,572
Greece, laterite ore	21,405	19,610	19,431	19,073	17,925
Guatemala, laterite ore	46,800	56,400	45,900	53,700	39,600
Indonesia, laterite ore	177,100	129,600	204,000 r	355,000 r	606,000
Kosovo, laterite ore[e]	6,720	7,420	4,270	7,120	6,550
Madagascar, laterite ore, nickel-cobalt sulfide[e, 5]	43,000	55,000	49,000	42,000 r	39,000
Morocco, undifferentiated or other, nickel hydroxide	220	203	188	196 r	200 e
New Caledonia, laterite ore	175,174	193,199	204,207	215,382	216,225
Norway, undifferentiated or other	400	285	220	206	210
Papua New Guinea, laterite ore, nickel-cobalt hydroxide[6]	20,987	25,582	22,269	34,666	35,355
Philippines, laterite ore	393,262 r	415,021 r	300,506 r	339,377 r	344,915
Russia:					
Laterite ore	11,200 e	7,400	7,000 e	1,800 e	--
Sulfide ore, concentrate[e]	272,000 r	269,000 r	252,000 r	266,000 r	272,000
South Africa, sulfide ore, concentrate	54,956	56,689	48,994	48,383	43,236
Spain, sulfide ore, concentrate	8,631	7,213	--	--	--
Turkey, laterite ore	3,500	9,900	10,680 r	17,000 r	17,000
United States, sulfide ore, concentrate	4,300	27,200	24,100	22,100	17,600
Venezuela, laterite ore	5,000	4,800	--	--	--
Vietnam, sulfide ore, concentrate	6,854	8,607	4,272	--	--
Zimbabwe, sulfide ore, concentrate	16,633	16,109	17,743	16,617	17,844
Total	2,130,000 r	2,110,000 r	2,010,000 r	2,190,000 r	2,400,000
Of which:					
Laterite ore	1,040,000 r	1,050,000 r	1,000,000 r	1,230,000 r	1,480,000
Sulfide ore	597,000 r	627,000 r	591,000 r	559,000 r	527,000
Undifferentiated or other	489,000	431,000	411,000 r	396,000	399,000

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

[1]Table includes data available through September 12, 2019. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, reported data represent a more highly processed form to provide an indication of the magnitude of mine output.

[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 calculated using data from South 32 Company.

[5]Often called mixed sulfide product or MSP.

[6]Often called mixed hydroxide product or MHP.

TABLE 11

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

(Metric tons, nickel content)

Country or locality	2014	2015	2016	2017	2018
Matte:					
Australia	61,541	44,268	38,247	36,812	13,600
Botswana	14,958	16,789	14,273	--	--
Canada[e, 3]	77,100	88,300	90,800	65,200	57,200
Finland	-- [r]	1,700 [r, e]	15,000 [r, e]	25,000 [r]	31,000
Indonesia[4]	78,726	81,177	77,581	76,807	74,806
New Caledonia	8,241	6,761	4,287	--	--
Russia[e, 5]	--	812	16,900	42,700	43,900
South Africa	7,700	400	--	--	--
Zimbabwe[6]	4,513 [r]	4,284 [r]	5,346 [r]	4,705 [r]	5,187
Total	253,000 [r]	245,000 [r]	262,000 [r]	251,000 [r]	226,000
Other:					
Cuba:[e]					
Ammoniacal liquor precipitate and unspecified	620	690	640	740 [r]	700
Nickel-cobalt sulfide[7]	36,700	36,700	34,800	35,200	34,800
New Caledonia, nickel-cobalt hydroxide[8]	12,464	9,686	7,269	6,525	6,723
Papua New Guinea, nickel-cobalt hydroxide[8]	20,987	25,582	22,269	34,666	35,355
Philippines, nickel-cobalt sulfide[7]	50,647	51,733	48,371	50,553	48,633
Turkey, nickel-cobalt hydroxide[8]	--	--	1,790	4,000	5,001
Total	121,000	124,000	115,000	132,000	131,000
Grand Total	374,000 [r]	369,000 [r]	377,000 [r]	383,000 [r]	357,000

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

[1]Table includes data available through September 13, 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]Includes matte and oxide sinter used as refinery feed.

[4]Represents the nickel output of the Soroako smelter. The Soroako matte was shipped to Japan for further processing.

[5]Nornickel shipped matte to the Harjavalta refinery in Finland.

[6]Zimplats matte shipped to the Impala refinery at Springs, South Africa.

[7]Often called mixed sulfide product or MSP.

[8]Often called mixed hydroxide product or MHP.

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

(Metric tons, nickel content)

Country or locality[3]	2014	2015	2016	2017	2018
Australia:					
Metal	129,862	132,074	117,920	108,500 r	113,500
Unspecified[4]	7,901	20,904	2,600	--	--
Total	137,763	152,978	120,520	108,500 r	113,500
Austria, ferronickel	1,000	1,000	1,000	1,000	1,000
Brazil:					
Ferronickel	34,501 r	54,700	68,600	68,500	65,200
Metal	19,823 r	22,650 r	--	--	--
Total	54,324 r	77,350 r	68,600	68,500	65,200
Burma, ferronickel[5]	14,900 r, e	15,600 r, e	16,800 r	16,200 r	15,000 e
Canada, unspecified	149,486	149,716	158,299	154,080 r	133,200
China:[6]					
Chemicals	20,000	18,891	29,100	39,900	45,200
Ferronickel, nickel pig iron[7]	471,500	385,035	374,745	411,462	476,040
Metal	247,000	236,700	221,700	205,000 e	195,000 e
Total	738,500	640,626	625,545	656,000 e	716,000 e
Colombia, ferronickel	41,221	36,671	37,092	40,600	43,100
Cuba, oxide sinter, including oxides[8]	13,252	14,667	15,006	15,751 r	16,000
Dominican Republic, ferronickel	--	--	9,913	15,632	19,214
Finland:					
Chemicals	5,964	7,129	8,048	8,358	10,330
Metal	36,639	36,350	45,606	51,342	50,435
Total	42,603	43,479	53,654	59,700	60,765
France, unspecified[9]	8,404	6,533	4,639	2,329	3,667
Greece, ferronickel	18,481	17,113	17,071	16,781	15,720
Guatemala, ferronickel	5,040	10,826	8,688	12,416	14,688
Indonesia:					
Ferronickel	16,851	17,211	20,293	21,762	24,868
Ferronickel, nickel pig iron[7]	--	27,200 e	75,900 r, e	74,800 r, e	73,300 e
Total	16,851	44,400 e	96,200 e	96,600 r, e	98,200 e
Japan:					
Chemicals	5,673	10,045	11,153	16,773	15,624
Ferronickel[e]	70,100	71,200	70,300	65,300	68,200
Metal	56,129	64,068	63,132	61,377	57,517
Oxide sinter	45,900 e	47,500 e	46,900 e	43,558 r	45,438
Total[e]	178,000	193,000	191,000	187,000	187,000
Korea, Republic of, ferronickel[10]	22,799	39,005	45,600	47,400	44,500
Kosovo, ferronickel	7,746	11,301	2,540	7,100 r	5,700
Macedonia, ferronickel	18,054	17,699	10,603	7,175	10,100
Madagascar, metal	37,053	47,271	42,105	35,474	33,183
Morocco, chemicals, nickel hydroxide	200 e	203	188	196 r	200 e
New Caledonia:					
Ferronickel	54,683	56,486	67,518	73,219	82,114
Oxide sinter	7,366	21,044	28,465	30,875	25,800
Total	62,049	77,530	95,983	104,094	107,914
Norway, metal	90,500	91,220	92,700	86,500	90,800
Russia:					
Chemicals	2,700	2,900	2,400 e	--	--
Metal	234,700	231,200	188,700	157,396	158,005
Total	237,400	234,100	191,000 e	157,396	158,005
South Africa:					
Chemicals[11]	3,500 e	5,300 e	4,743 r	4,966 r	5,295
Metal	39,356 r	41,910 r	42,332 r	42,362 r	40,093
Total	42,900 r, e	47,200 r, e	47,075 r	47,328 r	45,388

See footnotes at end of table.

TABLE 12—Continued

NICKEL: WORLD PRIMARY PRODUCTION, BY COUNTRY OR LOCALITY AND PRODUCT[1, 2]

(Metric tons, nickel content)

Country or locality[3]	2014	2015	2016	2017	2018
Taiwan	(10)	(10)	(10)	(10)	(10)
Ukraine, ferronickel[12]	18,600 e	18,000 e	18,100	15,300	15,807
United Kingdom, metal	39,100	38,804	45,194	25,781 r	25,000
Venezuela, ferronickel	5,000	4,000	--	--	--
Zimbabwe, metal[13]	2,915	617	--	--	--
Grand total	2,000,000	2,030,000	2,020,000 r	1,990,000 r	2,040,000
Of which:					
Chemicals	38,000 e	44,500 e	55,600 e	70,200 r	76,600
Ferronickel[e]	800,000 r	783,000	845,000 r	895,000 r	974,000
Metal	933,000 r	943,000 r	859,000	774,000 r	764,000
Oxide sinter	66,500 e	83,200 e	90,300 e	90,200 r	87,200
Unspecified	166,000	177,000	166,000	156,000 r	137,000

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

[1]Table includes data available through September 17, 2019. All data are reported unless otherwise noted. Grand totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Primary nickel refers to a nickel product ready for use by downstream consuming industries and includes nickel chemicals and salts, ferronickel, nickel metal in various forms, nickel oxide sinter, and nickel pig iron. The U.S. Geological Survey does not use the terms Class I and Class II nickel as defined by the International Nickel Study Group (INSG). However, nickel metal reported here is generally equivalent to Class I nickel which is defined by INSG as nickel with a minimum nickel content of 99% in the form of briquets, cathodes (that is, electrolytic nickel), flakes or powders, granules, pellets, and rondelles. Ferronickel, nickel oxide sinter, and nickel pig iron are classified by INSG as Class II. Chemicals, although typically produced at refineries, are differentiated from production of metal when feasible.

[3]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.

[4]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.

[5]Imports to other countries of ferronickel from Burma, assumed 26% nickel content.

[6]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 nickel pig iron from laterite ores imported from Indonesia, New Caledonia, and the Philippines.

[7]Nickel pig iron is a primary nickel product containing iron and nickel as primary constituents, but with a nickel content of less than 15%.

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

[9]Includes metal and nickel chloride.

[10]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.

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

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

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