USGS
science for a changing world

2019 Minerals Yearbook

NICKEL [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

August 2024

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 2019 decreased by 6% to 216,000 metric tons (t) compared with 230,000 t in 2018 (table 1). U.S. apparent consumption of primary nickel was 106,000 t, or about 4% of the 2.40 million metric tons (Mt) of world consumption reported by the International Nickel Study Group (INSG) (International Nickel Study Group, 2020b, p. A–1). Nickel alloy and stainless-steel production accounted for 45% and 40% of U.S. reported primary nickel consumption (table 4), respectively, in contrast with 8% and 70%, respectively, globally (Roskill Information Services Ltd., 2021b, p. 308). 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. U.S. industry melted 111,000 t of nickel contained in scrap, a 10% decrease from 123,000 t in 2018 (tables 1, 2).

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. However, some smelters and refineries add nickel-containing scrap to mined feed materials. 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 (electrolytic), flake, pellet, powder, rondelles, and so forth] discussed in this chapter has a purity of more than 99% and generally conforms to the INSG's definition of Class I nickel. Iron- and nickel-containing products, such as ferronickel and nickel pig iron (NPI), as well as nickel oxide sinter, have a purity less than 99% and 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 either 99.8% (ASTM International standards) or 99.9% (Chinese National Standards) (London Metal Exchange Ltd., undated). Nickel chemicals and salts are also often produced at nickel refineries but are differentiated from production of metal whenever feasible.

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 2,558 t in 2019, an 11% decrease compared with 2,872 t in 2018 (U.S. Mint, undated a, b).

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 2019, the Eagle Mine produced 13,500 t of nickel in concentrate, a 23% decrease compared with 17,600 t in 2018, which the company attributed primarily to a decrease in ore grade (Lundin Mining Corp., 2020b, p. 17).

Limited quantities of byproduct nickel were recovered at Sibanye Gold Ltd.'s [trading as Sibanye-Stillwater (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, LLC (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 2019. 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 sulfide minerals. The two sulfide concentrates were transported 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 2019, trade statistics from the U.S. Census Bureau indicated that 66% of total United States nickel concentrates exports went to Finland and 26% to Canada.

Lundin's Eagle East project was located approximately 2 kilometers (km) east and 600 meters deeper than the Eagle deposit and part of the same intrusive complex. The company estimated that average copper and nickel ore grades for Eagle East were approximately 60% higher compared with Eagle. In 2018, the company amended the Eagle Mine permit to include development of the Eagle East project using existing infrastructure and similar mining methods, which was expected to extend the mine life to 2025. By yearend 2019, development of Eagle East was nearly complete, and the project had begun contributing feed to the mill (Lundin Mining Corp., 2020a, p. 33–35, 37–38; 2020b, p. 17).

Minnesota.—PolyMet Mining Corp. (Canada) continued to advance its copper, nickel, and platinum-group-metal (PGM) NorthMet project. 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. In March, PolyMet received a wetlands permit from the U.S. Army Corps of Engineers, which was the last key permit

needed to construct and operate the project. The wetlands permit and several other permits issued by the State were subsequently challenged in court and were still unresolved at yearend 2019 (PolyMet Mining Corp., 2021, p. 4–7).

In December, Twin Metals Minnesota LLC submitted a mine plan of operations to the Bureau of Land Management and data to support an environmental assessment to the Minnesota Department of Natural Resources. The project targeted cobalt, copper, gold, nickel, PGMs, and silver mineralization of the Maturi deposit, part of the magmatic Duluth Complex, which was located approximately 14 km southeast of Ely and 18 km northeast of Babbitt. The company's proposal included development of an underground mine, tailings management facilities, and a plant to produce separate concentrates of copper and nickel and a gravity concentrate containing PGMs, gold, and silver (Twin Metals Minnesota LLC, 2019, p. 2, 3, 54).

Missouri.—Missouri Cobalt, LLC began operation of a newly constructed beneficiation plant to produce a cobalt-copper-nickel concentrate near Fredericktown, MO. In 2018, the company began environmental remediation at the Madison Mine, a former lead mine and Superfund site, and later applied for a permit to mine (U.S. Environmental Protection Agency, 2019; Missouri Cobalt, LLC, undated).

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 transported by truck 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 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 then was converted to a marketable nickel-cobalt-molybdenum alloy in a direct-current electric arc furnace (Stephan, 2013).

AMG Vanadium LLC announced that it would begin construction of a plant to recycle spent petroleum catalysts in Zanesville, OH, similar to the company's existing plant in Cambridge, OH. The company used proprietary roasting and pyrometallurgical processing to produce ferrovanadium and ferronickel-molybdenum, which were typically sold to carbon- and stainless-steel producers. The new plant would effectively double the company's catalyst recycling and ferroalloy production capacity (Newbanks, 2019).

Consumption

Reported primary nickel consumption in the United States was 105,000 t in 2019, a slight decrease compared with 107,000 t in 2018 (table 1). The estimated value of reported primary nickel consumption was $1.46 billion, a 4% increase compared with that in 2018, which was primarily the result of a 6% increase in the annual average LME cash price. U.S. industry consumed 13,200 t of ferronickel in 2019, of which 98% was used in stainless steels (tables 3, 4).

Stainless Steel and Low-Alloy Steels.—In 2019, stainless-steel producers accounted for 40% of reported primary nickel consumption, 68% 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 6% of U.S. primary nickel use. Production of raw stainless and heat-resisting steel in the United States decreased by 8% to 2.59 Mt. Production of nickel-bearing grades decreased by 10% to 1.87 Mt compared with that in 2018 and accounted for 72% of total stainless-steel production (American Iron and Steel Institute, 2019, 2020). Leading domestic stainless-steel producers included AK Steel Holding Corp. (West Chester Township, OH), Allegheny Technologies Inc. (ATI) (Pittsburgh, PA), North American Stainless (Ghent, KY), and Outokumpu Stainless USA, LLC (Calvert, AL).

In April 2019, the U.S. Department of Commerce denied ATI's request to exclude joint-venture company Allegheny & Tsingshan Stainless, LLC from the 25% tariff on imported stainless steel under section 232 of the Trade Expansion Act of 1962. ATI entered into the joint venture with the intent of improving capacity utilization, specifically by reopening its previously idled direct roll anneal and pickle operation in Midland, PA, to process stainless-steel slab imported from Indonesia. ATI submitted a new request in October 2019 and was awaiting a decision at yearend 2019 (Allegheny Technologies Inc., 2020, p. F–6).

Superalloys and Related Nickel-Base Alloys.—Of the primary nickel consumed in the United States in 2019, approximately 45% was used to make high-performance superalloys and other related nickel-containing 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).

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 2019, both globally and domestically. Roskill Information Services Ltd. (2021b, p. 308) estimated that battery consumption accounted for 5% (128,000 t) of global primary

nickel consumption in 2019. U.S. Geological Survey (USGS) end-use nickel statistics included battery consumption with the chemicals and chemical uses category, which accounted for 2% of domestic primary nickel consumption in 2019 (table 4).

Nickel was increasingly used in the cathode of many lithium-ion batteries. The primary advantage of nickel-containing battery cathodes is higher energy density compared with most non-nickel-containing alternatives, which is especially important for larger capacity batteries used in applications such as electric vehicles and stationary energy storage. Two of the most common nickel-containing cathode formulations are lithium-nickel-cobalt-aluminum (NCA) and lithium-nickel-cobalt-manganese (NCM), which together have been estimated to account for 57% of global battery cathode production (Roskill Information Services Ltd., 2021a, p. 4). 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 increased, the amount of cobalt used decreased. This helped reduce cost and risks associated with cobalt availability (Nickel Institute, 2021; Vale S.A., undated, p. 9–10).

The USGS annual nickel consumption survey was sent to domestic consumers of primary nickel products. To adequately capture domestic nickel consumption in lithium-ion batteries, this included canvassing domestic producers of cathode materials. However, 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.

ZAF Energy Systems, Inc. announced that it would expand production capacity at its nickel-zinc manufacturing plant in Joplin, MO, from hundreds of batteries per month to thousands of batteries per month, owing to a strategic investment from Wirtz Manufacturing, a global manufacturer of lead-acid batteries. In October, ZAF announced that it was awarded a $1.4 million contract by the U.S. Air Force for development of a prototype energy storage system to support the intercontinental ballistic missile ground facility. The system would power the silo's systems in the event of a power outage until standby generators could be started. According to the company, nickel-zinc batteries have a number of advantages over lead-acid batteries including smaller size and weight, longer operational life, and greater power and storage capacity. It also was reported that nickel-zinc batteries were able to be stored for up to 20 years without recharging and, unlike lithium-ion batteries, do not require a battery management system, although one could be used in critical applications (Missouri Partnership, 2019; ZAF Energy Systems, Inc., 2019).

Stocks

Global stocks of nickel metal held in LME-approved warehouses decreased by 26% to 153,318 t at yearend 2019 compared with 206,400 t at yearend 2018. All stocks in LME-approved warehouses were Class I material (refined products with a nickel content of 99% or greater) (London Metal Exchange Ltd., 2018, 2019).

Data collected by the INSG indicated that in December 2019 world nickel producers held 91,400 t of primary nickel stocks, a 6% increase compared with stocks at yearend 2018 (International Nickel Study Group, 2020b, p. A–1). At yearend 2019, U.S. consumer stocks of primary nickel totaled 6,860 t, a slight increase compared with yearend 2018 (tables 1, 5).

Prices

According to S&P Global Platts Metals Week, the LME average annual cash price for nickel was $13,903 per metric ton, a 6% increase compared with $13,114 per metric ton in 2018 (table 1).

World Review

In 2019, global mine production of nickel increased by 9% to 2.61 Mt (table 10). Production from laterite deposits increased by 15% and accounted for 65% of global mine production. 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 ore and other deposit types was essentially unchanged from that in 2018. Global primary production increased by 9% to 2.24 Mt compared with 2.06 Mt (revised) in 2018 (table 12). Production of ferronickel, including NPI, increased by 22% and accounted for more than one-half of total primary nickel production. Production of all other forms of primary nickel decreased in 2019 compared with production in 2018.

According to the INSG, world consumption of primary nickel increased by 3% to 2.40 Mt (International Nickel Study Group, 2020b, p. A–1). Stainless steel accounted for about 70% of global primary nickel consumption. World production of stainless and heat-resisting steel was 52.2 Mt in 2019, a slight increase compared with 50.7 Mt in 2018. China was the leading producer of stainless steel, accounting for 56% of world output and, as a result, was also the leading nickel consumer (International Stainless Steel Forum, 2020, p. 7, 12). On a global basis, alloy steels other than stainless accounted for 8% of primary nickel use; nonferrous alloys, 8%; electroplating and other surface finishing, 7%; batteries, 5%; and other applications including catalysts, chemicals, and powder metallurgy, 2% (Roskill Information Services Ltd., 2021b, p. 308).

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. Mine production was 158,751 t, essentially unchanged compared with 2018 (table 10). Australia ranked sixth in primary nickel output and during the previous 3 years had produced only refined metal. Primary production decreased by 7% to 106,470 t (table 12). All of the country's active mines and processing facilities were located in Western Australia (Department of Industry, Innovation and Science, 2019, p. 103).

Many of the country's mines and processing facilities were on care-and-maintenance status although numerous restarts were planned or implemented. Panoramic Resources Ltd. restarted operations at its Savannah Mine, and First Quantum Minerals Ltd. of Canada was preparing to restart operations at its Ravensthorpe Mine and hydrometallurgical processing plant. After executing an ore tolling and concentrate purchase agreement with BHP Billiton Ltd. (BHP), Mincor Resources NL planned a comprehensive restart of operations including the Cassini, Durkin North, and Long Mines. Poseidon Nickel Ltd. was preparing a final investment decision for the restart of its Black Swan Mine (Erkan, 2019; Riekie, 2019, p. 3; Southam, 2019, p. 13, 18; First Quantum Minerals Ltd., 2020, p. 15).

BHP's continued construction of a full-scale plant to produce nickel sulfate at its Nickel West Kwinana refinery. Stage 1 of the project would have a capacity of 100,000 metric tons per year (t/yr) using the refinery's high-purity nickel briquets and powder as feed material and was expected to begin production in 2020. The company also advanced projects to increase its nickel resource base including the commissioning of two new mines—the Mt. Keith satellite mine (also known as Yakabindie) and the Venus Mine—and development of the Leinster B11 Mine. According to the company, development projects and acquisitions contributed to an estimated 90% increase in its nickel reserves since 2017. BHP also expected that the tolling agreement with Mincor would allow it to restart its Kambalda concentrator, which had been placed on care-and-maintenance status in 2018 (BHP Billiton Ltd., 2020, p. 84; Haegel, 2020, p. 7–11).

Brazil.—In 2019, Brazil's mine production decreased by 19% to 60,600 t, and total plant production decreased by 17% to 54,221 t compared with that in 2018. 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 2019, all plant production was in the form of ferronickel. Ferronickel was produced at Anglo American plc's (United Kingdom) 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., 2020, p. 58).

In June, Vale suspended operations at its Onça Puma ferronickel plant in response to a Federal court order. Vale's associated mining operations had been suspended since 2017, when a Federal court ordered mining operations to halt until reparations were made to the indigenous community after determining that the company was responsible for metal contamination in the Catete River near the operation. Vale appealed the June ruling and in September 2019 reached an agreement with the court to restart both mining and processing operations. In 2019, Onça Puma produced 11,600 t of nickel in ferronickel, a 49% decrease compared with that in 2018 (Vale S.A., 2019a, p. 157; 2020, p. 58, 60, 163).

Canada.—Globally, Canada ranked fifth in both nickel mine and primary nickel production. Mine production was 181,410 t, a slight increase compared with 2018. Plant production decreased by 9% to 124,736 t (tables 10, 12). Four Provinces had active nickel mines in 2019—Manitoba, Newfoundland and Labrador, Ontario, and Quebec.

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 by industry), and nickel-cobalt sulfide (often called mixed sulfide product or MSP by industry) to supply its primary 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, 2020a, p. B–23—B–29). Imports of nickel ore and concentrate were 56.2 Mt (gross weight) in 2019, an increase of 20% compared with those in 2018. Indonesia and the Philippines were the leading suppliers accounting for 42% and 54%, respectively (International Nickel Study Group, 2020b, p. B–13).

In 2019, China's total primary production was 826,640 t, an increase of 16% compared with that in 2018, and accounted for 37% of world primary nickel production. Production of NPI, a form of ferronickel with a nickel content less than 15%, increased by 26% to reach 73% of China's production of primary nickel and production of chemicals and metal decreased by 9% and 3%, respectively (table 12).

According to INSG data, China was the world's leading consumer of nickel. Consumption was 1.33 Mt of primary nickel, an 11% increase compared with 1.20 Mt in 2018, and which accounted for 55% of world consumption in 2019. China's imports of unwrought, unalloyed nickel (Harmonized System code 7502.10) were 193,000 t, a decrease of 9% compared with 212,000 t in 2018. Imports from Russia accounted for 46%, followed by Australia (24%), and Canada (7%). Gross weight imports of ferronickel, which likely included NPI, were 1.90 Mt, more than double that in 2018. Ferronickel imports from Indonesia more than doubled and accounted for 71% of China's ferronickel imports (International Nickel Study Group, 2020b, p. A–6, B–14—B–15).

Guatemala.—Mine production in Guatemala was 36,300 t, a 7% decrease compared with 39,200 t in 2018 (table 10). Production of ferronickel was 20,323 t, a 38% increase compared with 14,688 t in 2018 (table 12). In July, the Constitutional Court suspended Compañía Guatemalteca de Níquel, S.A.'s (CGN's) license to operate the Fenix Mine in the Department of Izabal to investigate claims that indigenous communities were not consulted when the license was issued in 2016. In addition to the Fenix operation, the company owned the rights to mine the Montafur project in the same vicinity. CGN sold part of its production to Compañía Procesadora de Níquel de Izabal, S.A. for the production of ferronickel and also produced direct-shipping ore for export (Harris, 2019; Solway Investment Group Ltd., 2020; Compañía Guatemalteca de Níquel, S.A., undated).

Indonesia.—In 2019, Indonesia was the leading global producer of mined nickel, producing 853,000 t, a 41% increase compared with 606,000 t in 2018 (table 10). The country also emerged as the second-ranked producer of primary nickel globally and a globally significant producer of stainless steel. Primary nickel production more than doubled to 205,000 t compared with that in 2018 (table 12). Increased production was primarily the result of the continued development and

commissioning of NPI smelters, which had been stimulated through implementation of a ban on the export of unprocessed ore beginning in 2014. The ban was eased in 2017 to permit export of ores with a nickel content of 1.7% or less if a company could demonstrate that 30% of its nickel mine production was used as feed at its own processing plant in Indonesia (Home, 2017). Prior to 2014, only two plants processed nickel ore—Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk's (Antam's) Pomalaa ferronickel smelter in Southeast Sulawesi and PT Vale Indonesia Tbk's Sorowako smelter in South Sulawesi that produced intermediate nickel matte, which was exported to Japan for further refining (tables 11, 12). By yearend 2019, the Government reported that nine additional smelters that primarily produced NPI had been put into operation (Ministry of Energy and Mineral Resources, 2020, p. 7).

In September, the Government announced that it would reinstate the ban on export of direct-shipping ore beginning January 1, 2020. The intent of the ban was to ensure the long-term supply of ore for domestic processing facilities. The Government also stated its intention to explore opportunities to process the lower grade limonite ore for use in electric vehicle batteries (Ministry of Energy and Mineral Resources, 2019).

Several companies were advancing projects to build 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 continued construction on a plant to produce 37,000 t/yr of nickel and 5,000 t/yr of cobalt in MHP on Obi Island. At the Morowali Industrial Park, PT QMB New Energy Materials, a partnership among GEM Co., Ltd. (China), Brunp Recycling Technology Co., Ltd. (China), Tsingshan Holding Group (China), PT Indonesia Morowali Industrial Park, and Hanwa Co. Ltd. (Japan), broke ground on a project to produce nickel sulfate for the battery market, and PT Huayou Nickel and Cobalt reportedly was constructing a plant to produce 60,000 t/yr of MHP. Sumitomo Metal Mining Co., Ltd. (Japan) and Vale (Brazil) worked on a definitive feasibility study to build an HPAL plant in southeast Sulawesi with a capacity to produce 40,000 t/yr of MSP (Daly and others, 2019; Nangoy and Asmirini, 2019; Sumitomo Metal Mining Co., Ltd., 2019b, p. 46).

Japan.—Japan ranked third in global primary nickel production, but all feed material was imported owing to a lack of domestic nickel mines. Primary production in 2019 was 183,000 t, a slight decrease compared with that in 2018. Japan produced, in descending order of nickel content, 58,777 t of metal, 58,000 t of ferronickel, 50,000 t of oxide sinter, and 16,132 t of nickel chemicals (table 12).

Sumitomo operated three nickel-processing facilities in the country. The Hyuga Smelter in Miyazaki Prefecture produced ferronickel shot from New Caledonian ore. Niihama Nickel Refinery in Ehime Prefecture produced electrolytic nickel, nickel chloride, and nickel sulfate from MSP from the Coral Bay Nickel Corp. and Taganito HPAL Nickel Corp. plants in the Philippines, nickel matte from PT Vale in Indonesia, and additional raw materials from elsewhere. Sumitomo's Harima refinery in Hyogo Prefecture processed MSP from Coral Bay Nickel and Taganito to produce separate sulfates of nickel and cobalt. Some of the company's refined nickel products were used to produce battery cathode materials at the company's Isoura Battery Materials plant in Niihama and Sumiko Energy Materials Co., Ltd.'s plant in Fukushima. In March 2019, Sumitomo began operation of a pilot plant to separately recover cobalt, copper, and nickel from spent lithium-ion batteries in a form conducive for reuse in new lithium-ion batteries using a combination of hydrometallurgical and pyrometallurgical processing. The recycling project was part of the company's long-term strategy to increase battery cathode production capacity and improve collaboration among its mineral resource, smelting and refining, and materials business units (Sumitomo Metal Mining Co., Ltd., 2019a; 2019b, p. 46–47, 66).

New Caledonia.—New Caledonia ranked fourth in nickel mine production and eighth in primary production. Mine production was 208,185 t, a decrease of 4% compared with that in 2018 (table 10). Total primary production was 87,921 t, a decrease of 19% compared with that in 2018, of which 70,654 t was in the form of ferronickel and 17,267 t was nickel oxide sinter (table 12). New Caledonia also produced 6,483 t of MHP, which was exported for further processing (table 11).

As part of its ongoing initiatives to restore Société Le Nickel's (SLN's) operations to profitability, Eramet S.A. announced that it had been granted permission from the Government to export up to 4 million metric tons per year of lower grade ore (in this case, ore with a nickel content of less than 1.8%). According to the company, because its Doniambo ferronickel plant in Noumea processed higher grade ore, approval to export lower grade ore would facilitate more effective use of its resources. By yearend 2019, SLN had exported 1.6 Mt gross weight direct-shipping ore (approximately 29,000 t on a nickel content basis assuming an average ore grade of 1.8% nickel). Doniambo's ferronickel production, however, decreased by 13% to 47,400 t compared with that in 2018, owing primarily to an ongoing labor dispute which disrupted ore supply to the plant (Eramet, S.A., 2019; 2020, p. 54, 56).

Throughout 2019, Vale Nouvelle-Calédonie S.A.S. continued to experience ongoing challenges in production and processing at its Goro hydrometallurgical plant. Although initially designed to produce 50,000 t/yr of nickel as nickel oxide and nickel hydroxide through HPAL processing of limonite and saprolite ores, in 2019, the operation only attained production of 23,400 t, a decrease of 28% compared with that in 2018. Vale concluded that it would be necessary to indefinitely reduce future expected production levels and was evaluating alternatives to dispose of the operation. The company also decided to simplify the operation's flow sheet by discontinuing production of fully refined nickel oxide and cobalt carbonate and instead focus on production of intermediate MHP, which was expected to be in high demand from the battery market (Vale S.A., 2019b, p. 26; 2020, p. 17, 57, 60, F–61).

Philippines.—The Philippines ranked second in global mine production, with 323,325 t, a decrease of 6% compared with that in 2018 (table 10). In 2019, nickel accounted for the highest share (49%) of the country's total metallic mineral production value for the second consecutive year. Operations at 13 of 31 nickel mines remained on care-and-maintenance status at yearend 2019, many of which were suspended 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, 2020).

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. (Japan), Sojitz Corp. (Japan), 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 production and fourth in primary production in 2019. Mine production increased slightly to 279,000 t compared with that in 2018 and primary production was 166,265 t in carbonyl and electrolytic cathode nickel, an increase of 5% compared with that in 2018 (tables 10, 12). All production was from the operations of PJSC MMC Norilsk Nickel (Nornickel). The company mined and beneficiated nickel-copper sulfide ores and smelted the concentrates at its Polar Division on the Taymyr Peninsula and at Kola MMC on the Kola Peninsula. Matte from the Polar Division was refined at Kola MMC's Severonickel refinery at Monchegorsk on the Kola Peninsula. Matte from Kola MMC was refined at Severonickel and at Norilsk Nickel Harjavalta Oy in Finland. Nornickel continued to implement upgrades with the goal of increasing refined nickel capacity from 120,000 t/yr to 145,000 t/yr. In 2019, the company was finalizing refurbishment of electrowinning cells at Monchegorsk and expected to begin ramping up the project to full capacity in 2020. Nornickel also announced its intention to close its nickel smelter in Murmansk in an effort to reduce sulfur dioxide emissions by 50% (PJSC MMC Norilsk Nickel, 2020, p. 38, 40).

South Africa.—In 2019, mine production was 42,936 t, essentially unchanged from that in 2018, and primary production was 43,700 t, a slight decrease compared with that in 2018 (tables 10, 12). Most nickel production was recovered as a byproduct of PGM mining.

In August, African Rainbow Minerals Ltd. announced that it intended to place its Nkomati Mine on care-and-maintenance status no later than September 2020. The nickel sulfide mine, located in Mpumalanga Province, was a joint venture with Nornickel (Thomson Reuters, 2019).

Thakadu Battery Materials Pty. Ltd finished construction and began commissioning its nickel sulfate plant at Sibanye-Stillwater's Marikana operation (formerly owned by Lonmin plc). The Thakadu facility was designed to purify Marikana's crude nickel sulfate with a production target of 25,000 t/yr of nickel sulfate (5,500 t/yr nickel content) for the battery market (Seccombe, 2019).

Outlook

From 2009 to 2019, global nickel consumption had a compound annual growth rate of approximately 7% (International Nickel Study Group, 2020b, p. A–1). Stainless steel has been and is expected to continue to be the leading end use of primary nickel, although its share of primary nickel consumption is likely to decrease as a shift to vehicle electrification drives increased consumption of nickel in lithium-ion batteries (Backeberg and others, 2020, p. 13). World stainless melt shop production (gross weight) has had a long-term compound annual growth rate of 5.8%, climbing from 1 Mt in 1950 to 52.2 Mt in 2019. Chromium-nickel grades (300 series) constitute more than 50% of stainless-steel production (International Stainless Steel Forum, 2020, p. 3, 14).

Even the most conservative projections of the emerging demand for nickel-containing batteries anticipate a significant disruption to nickel supply in coming years. Roskill Information Services Ltd. (2021b, p. 84, 308) estimated that nickel consumption in batteries would increase from 128,000 t in 2019 to more than 1.20 Mt by 2030. Most of that increase is attributed to the automotive industry, as the pace of electric vehicle adoption has been accelerating owing to increased regulation of vehicle emissions, and as battery cathode chemistry shifts to higher nickel content (Backeberg and others, 2020, p. 14). 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); matte; or from MHP or MSP produced from HPAL processing. 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 refined products (such as chemicals, metal, and oxide sinter), production of which has been decreasing since 2015 (table 12).

References Cited

Allegheny Technologies Inc., 2020, 2019 annual report: Pittsburgh, PA, Allegheny Technologies Inc., February 25, 104 p. (Accessed February 16, 2022, at https://s27.q4cdn.com/226628310/files/doc_financials/2019/ar/ati-2019-annual-report-full-final.pdf.)

American Iron and Steel Institute, 2019, Quarterly production of stainless and heat resisting raw steel (AIS 104)—Fourth quarter [2018]: Washington, DC, American Iron and Steel Institute, 2 p.

American Iron and Steel Institute, 2020, Quarterly production of stainless and heat resisting raw steel (AIS 104)—Fourth quarter 2019: Washington, DC, American Iron and Steel Institute, 2 p.

Anglo American plc, 2015, Mine profile—Barro Alto: London, United Kingdom, Anglo American plc, October 6. (Accessed February 22, 2022, at http://www.angloamerican.com/media/our-stories/mine-profile-barro-alto.)

Backeberg, N., Masson, O., Lu, Y., and Anderson, J., 2020, Nickel—Stainless steel vs batteries vs COVID-19: Roskill Information Services Ltd., May 2020, 20 p.

BHP Billiton Ltd., 2020, Annual report 2020: Melbourne, Victoria, Australia, BHP Billiton Ltd., 352 p. (Accessed March 4, 2022, at https://www.bhp.com/-/media/documents/investors/annual-reports/2020/200915_bhpannualreport2020.pdf.)

Compañía Guatemalteca de Níquel, S.A., [undated], Our history: Izabal, Guatemala, Compañía Guatemalteca de Níquel, S.A. (Accessed February 23, 2022, at https://cgn.com.gt/nusetra-historia2/.)

Daly, T., Leng, C., and Singh, S., 2019, China Moly joins Huayou in Indonesia nickel project: Vancouver, British Colombia, Canada, Mining.com, November 10. (Accessed March 2, 2022, at https://www.mining.com/web/china-moly-joins-huayou-in-indonesia-nickel-project/.)

Department of Industry, Innovation and Science [Australia], 2019, Resources and energy quarterly—December 2019: Canberra, Australian Capital Territory, Australia, Department of Industry, Innovation and Science, 161 p. (Accessed March 4, 2022, at https://publications.industry.gov.au/publications/resourcesandenergyquarterlydecember2019/documents/Resources-and-Energy-Quarterly-December-2019.pdf.)

Eramet S.A., 2019, Eramet—The government of New Caledonia gives the green light to SLN's nickel ore exports: Paris, France, Eramet S.A. press release, April 16, 2 p. (Accessed March 1, 2022, at https://www.eramet.com/sites/default/files/import/press_release/pdf/pr_sln_exports_en.pdf.)
Eramet S.A., 2020, Universal registration document 2019: Paris, France, Eramet S.A., 426 p. (Accessed August 30, 2022, at https://www.eramet.com/sites/default/files/2020-04/Eramet-2019-Universal-Registration-Document.pdf.)
Erkan, Berkay, 2019, Panoramic Resources makes first polymetallic concentrate shipment from recommissioned Savannah Mine: Perth, Western Australia, Australia, Proactive Australia PTY Ltd., February 14. (Accessed March 4, 2022, at https://www.proactiveinvestors.com.au/companies/news/214605/panoramic-resources-makes-first-polymetallic-concentrate-shipment-from-recommissioned-savannah-mine-214605.html.)
First Quantum Minerals Ltd., 2020, Management's discussion and analysis for the year ended December 31, 2019: Perth, Western Australia, Australia, First Quantum Minerals Ltd., February 13, 59 p. (Accessed March 4, 2022, at https://s24.q4cdn.com/821689673/files/doc_financial/2019/q4/Q4-2019-FQM-Management's-Discussion-Analysis-(FINAL).pdf.)
Haegel, Eduard, 2020, Towards a sustainable future: Melbourne, Victoria, Australia, BHP Billiton Ltd. presentation, October 13, 20 p. (Accessed March 4, 2022, at https://www.bhp.com/-/media/documents/media/reports-and-presentations/2020/eddy-haegeldiggers--dealers-2020--final.pdf?la=en.)
Harris, Paul, 2019, Fenix grounded in Guatemala: Mining Journal, July 22. (Accessed February 23, 2022, at https://www.mining-journal.com/base-metals/news/1367883/fenix-grounded-in-guatemala.)
Home, Andy, 2017, Indonesia rocks the nickel market (again): Thomson Reuters, January 13. (Accessed March 2, 2022, at https://www.reuters.com/article/us-indonesia-nickel-ahome/indonesia-rocks-the-nickel-market-andy-home-idUSKBN14Y00Z.)
Horsehead Holding Corp., 2015, Form 10–K—2015: U.S. Securities and Exchange Commission, 76 p. plus exhibits. (Accessed January 5, 2022, at https://www.sec.gov/Archives/edgar/data/1385544/000119312516725704/d236839d10k.htm#tx236839_11.)
International Nickel Study Group, 2020a, World directory of nickel production: Lisbon, Portugal, International Nickel Study Group, 5 sections (A–E).
International Nickel Study Group, 2020b, World nickel statistics—Yearbook: Lisbon, Portugal, International Nickel Study Group, v. 29, no. 12, November, 4 sections (A–D).
International Stainless Steel Forum, 2020, Stainless steel in figures 2020: Brussels, Belgium, International Stainless Steel Forum, 22 p. (Accessed January 7, 2022, at https://www.worldstainless.org/Files/issf/non-image-files/PDF/ISSF_Stainless_Steel_in_Figures_2020_English_public_version.pdf.)
London Metal Exchange Ltd., 2018, Nickel stocks: London, United Kingdom, London Metal Exchange Ltd., December 31.
London Metal Exchange Ltd., 2019, Nickel stocks: London, United Kingdom, London Metal Exchange Ltd., December 31.
London Metal Exchange Ltd., [undated], LME Nickel—Contract specifications: London, United Kingdom, London Metal Exchange Ltd. (Accessed January 5, 2022, via https://www.lme.com/Metals/Non-ferrous/LME-Nickel/Contract-specifications.)
Lundin Mining Corp., 2020a, Annual information form for the year ended December 31, 2019: Toronto, Ontario, Canada, Lundin Mining Corp., March 27, 100 p. (Accessed August 26, 2020, at https://lundinmining.com/site/assets/files/7863/lmc_-_2019_aif_-_032720.pdf.)
Lundin Mining Corp., 2020b, Management's discussion and analysis for the year ended December 31, 2019: Toronto, Ontario, Canada, Lundin Mining Corp., February 20, 32 p. (Accessed February 16, 2022, at https://lundinmining.com/site/assets/files/8020/lundin_mining_-_2019_ye.pdf.)
Mayyas, A., Steward, D., and Mann, M., 2018, Impact of Li-ion battery recycling on the supply chain: The Cobalt Conference, Cobalt Institute, Las Vegas, NV, May 23–24, presentation, 31 p. (Accessed January 7, 2022, at https://www.nrel.gov/docs/fy20osti/71610.pdf.)
Mines and Geosciences Bureau [Philippines], 2019, 2018 yearend review: Quezon City, Philippines, Mines and Geosciences Bureau, February 28, 6 p. (Accessed February 18, 2022, at https://mgb.gov.ph/attachments/article/689/YearEndReview2018Asof02282019.pdf.)
Mines and Geosciences Bureau [Philippines], 2020, 2019 year end review: Quezon City, Philippines, Mines and Geosciences Bureau, April 15, 5 p. (Accessed February 18, 2022, at https://mgb.gov.ph/images/Year_End_Review_2019_04-15-2020.pdf.)
Ministry of Energy and Mineral Resources [Indonesia], 2019, Nickel ore should not be exported again as of January 2020: Jakarta, Indonesia, Ministry of Energy and Mineral Resources, September 2. (Accessed March 2, 2022, at https://www.esdm.go.id/en/media-center/news-archives/bijih-nikel-tidak-boleh-diekspor-lagi-per-januari-2020.) [In Indonesian.]
Ministry of Energy and Mineral Resources [Indonesia], [2020], Strategic plan of the Directorate General of Mineral and Coal 2020–2024: Jakarta, Indonesia, Ministry of Energy and Mineral Resources, 205 p. (Accessed March 2, 2022, at https://www.minerba.esdm.go.id/pdf/172-Renstra%20DJMB%20Tahun%202020-2024.) [In Indonesian.]
Missouri Cobalt, LLC, [undated], Our projects: St. Louis, MO, Missouri Cobalt, LLC. (Accessed August 31, 2022, at https://www.mocobalt.com/projects.)
Missouri Partnership, 2019, Energy solutions company ramps up production in Missouri with new investment: Kansas City, MO, Missouri Partnership news release, February 26. (Accessed February 18, 2022, at https://www.missouripartnership.com/energy-solutions-company-ramps-up-production-in-missouri-with-new-investment/.)
Nangoy, F., and Asmarini, W., 2019, Indonesia battery-grade nickel plant awaits environmental nod—Developer: Thomson Reuters, April 5. (Accessed March 2, 2022, at https://www.reuters.com/article/indonesia-nickel/indonesia-battery-grade-nickel-plant-awaits-environmental-nod-developer-idUSL3N21K2J0.)
Newbanks, Michele, 2019, AMG Vanadium to build in Muskingum: The Parkersburg News and Sentinel [Zanesville, OH], July 14. (Accessed February 18, 2022, at https://www.newsandsentinel.com/news/business/2019/07/amg-vanadium-to-build-in-muskingum/.)
Nickel Institute, 2021, Nickel energizing batteries: Toronto, Ontario, Canada, Nickel Institute, [2] p. (Accessed January 5, 2022, at https://nickelinstitute.org/media/8d926a8a54d694a/2021-review-ni_energizing-batteries-v3.pdf.)
Nickel Institute, [undated], Nickel in batteries: Toronto, Ontario, Canada, Nickel Institute. (Accessed January 5, 2022, at https://www.nickelinstitute.org/about-nickel/nickel-in-batteries.)
PJSC MMC Norilsk Nickel, 2018, Annual report 2017—Investing in sustainable development: Moscow, Russia, PJSC MMC Norilsk Nickel, 295 p. (Accessed September 26, 2018, at https://www.nornickel.com/upload/iblock/f36/Annual_Report_2017.pdf.)
PJSC MMC Norilsk Nickel, 2020, Expanding the horizons of sustainable growth—Annual report 2019: Moscow, Russia, PJSC MMC Norilsk Nickel, 335 p. (Accessed March 3, 2022, at https://ar2019.nornickel.com/.)
PolyMet Mining Corp., 2021, Annual information form for the year ended December 31, 2020: Toronto, Ontario, Canada, PolyMet Mining Corp., March 18, 60 p. (Accessed February 17, 2022, at https://polymetmining.com/wp-content/uploads/2021/03/SEDAR-2020-AIF.pdf.)
Riekie, David, 2019, Poseidon Nickel—Primed for the nickel revival: West Perth, Western Australia, Australia, Poseidon Nickel Ltd. presentation, November 28, 25 p. (Accessed March 4, 2022, at http://poseidon-nickel.com.au/wp-content/uploads/2019/11/2019-AGM-Presentation-ASX-FINAL-281119.pdf.)
Roskill Information Services Ltd., 2021a, Cathode and precursor materials—Outlook to 2030, 1st edition: London, United Kingdom, Roskill Information Services Ltd., 362 p.
Roskill Information Services Ltd., 2021b, Nickel—Outlook to 2030, 17th edition: London, United Kingdom, Roskill Information Services Ltd., 206 p.
Seccombe, Allan, 2019, SA's Thakadu plunges into global nickel sulphate market: Business Day [Johannesburg, South Africa], April 1. (Accessed March 3, 2022, at https://www.businesslive.co.za/bd/companies/mining/2019-04-01-sas-thakadu-plunges-into-global-nickel-sulphate-market/.)
Sibanye Gold Ltd., 2017, Sibanye successfully concludes the acquisition of Stillwater: Westonaria, South Africa, Sibanye Gold Ltd. press release, May 4. (Accessed February 16, 2021, at https://thevault.exchange/?get_group_doc=245/1493909905-sgl-sibanye-successfully-concludes-stillwater-acquisition-04may2017.pdf.)
Solway Investment Group Ltd., 2020, Solway Investment Group announces its full year 2019 financial results: Zug, Switzerland, Solway Investment Group Ltd., July 13. (Accessed February 23, 2022, at https://solwaygroup.com/2020/07/13/solway-investment-group-announces-its-full-year-2019-financial-results/.)
Southam, David, 2019, Equity capital raising: West Perth, Western Australia, Australia, Mincor Resources NL, November, 39 p. (Accessed March 4, 2022, at https://www.mincor.com.au/site/PDF/4e2b8899-ef0a-485b-a2cc-a7d148a0f67d/Presentation.)

Stephan, B.J., 2013, Refining refiners spent catalysts: Craven Arms, United Kingdom, Digitalrefining.com, Crambeth Allen Publishing Ltd., March, 4 p. (Accessed January 5, 2022, via https://www.digitalrefining.com/article/1000782/refining-refiners-spent-catalysts#.XyiIHp5KhPY.)
Stillwater Mining Co., 2017, Form 10–K—2016: U.S. Securities and Exchange Commission, 108 p. (Accessed February 16, 2021, at https://www.sec.gov/Archives/edgar/data/931948/000093194817000012/swc-12312016x10k.htm.)
Sumitomo Metal Mining Co., Ltd., 2019a, Development of a new recycling process for lithium ion secondary batteries and operation of a pilot plant: Tokyo, Japan, Sumitomo Metal Mining Co., Ltd. press release, March 28. (Accessed January 10, 2022, at https://www.smm.co.jp/en/news/release/uploaded_files/20190328_E.pdf.)
Sumitomo Metal Mining Co., Ltd., 2019b, Integrated report 2019: Tokyo, Japan, Sumitomo Metal Mining Co., Ltd., 258 p. (Accessed January 10, 2022, at https://www.smm.co.jp/en/ir/library/integrated_report/pdf/2019/2019_All_EN.pdf.)
Thomson Reuters, 2019, African Rainbow Minerals to moth-ball loss-making Nkomati Mine: Thomson Reuters, August 30. (Accessed March 3, 2022, at https://www.reuters.com/article/african-rainbow-nkomati-idUSL5N25Q4HK.)
Twin Metals Minnesota LLC, 2019, Mine plan of operations: St. Paul, MN, Twin Metals Minnesota LLC, 102 p. (Accessed February 17, 2022, via https://www.twin-metals.com/resource/twin-metals-minnesota-mine-plan-of-operations/.)
U.S. Environmental Protection Agency, 2019, "Cobalt mine" in Fredericktown, Missouri, is focus of EPA Administrator and Rep. Jason Smith recognition event: Fredericktown, MO, U.S. Environmental Protection Agency news release, July 31. (Accessed March 3, 2022, at https://www.epa.gov/newsreleases/cobalt-mine-fredericktown-missouri-focus-epa-administrator-and-rep-jason-smith.)
U.S. Mint, [undated]a, Circulating coin production: Washington, DC, U.S. Mint. (Accessed January 5, 2022, via https://www.usmint.gov/about/production-sales-figures/circulating-coins-production.)
U.S. Mint, [undated]b, Coin specifications: Washington, DC, U.S. Mint. (Accessed January 5, 2022, at https://www.usmint.gov/learn/coin-and-medal-programs/coin-specifications.)
Vale S.A., 2019a, Form 20–F—2018: U.S. Securities and Exchange Commission, 195 p. plus financial statements. (Accessed February 22, 2022, via http://www.vale.com/EN/investors/information-market/annual-reports/20f/Pages/default.aspx.)
Vale S.A., 2019b, Vale day 2019: Rio de Janeiro, Brazil, Vale S.A. transcript, December 2, 45 p. (Accessed March 1, 2022, at http://www.vale.com/EN/investors/information-market/presentations-webcast/PresentationsWebcastsDocs/Transcript%20Vale%20Day%20London%202019.pdf.)
Vale S.A., 2020, Form 20–F—2019: U.S. Securities and Exchange Commission, April 3, 201 p. plus financial statements. (Accessed February 22, 2022, via http://www.vale.com/EN/investors/information-market/annual-reports/20f/Pages/default.aspx.)
Vale S.A., [undated], Electric vehicle revolution and implications for the nickel market: Rio de Janeiro, Brazil, Vale S.A. presentation, 21 p. (Accessed August 26, 2022, at http://www.fullertreacymoney.com/system/data/files/PDFs/2017/October/20th/Vale_EV%20and%20Nickel%20-%20Conference%20Oct%202017v3.pdf.)
Wood Mackenzie Ltd., 2017, A demanding supply problem for nickel: Edinburgh, United Kingdom, Wood Mackenzie Ltd., November. (Accessed August 26, 2020, via https://www.woodmac.com/news/editorial/how-will-electric-vehicles-affect-nickel/.)
ZAF Energy Systems, Inc., 2019, US Air Force contract awarded to ZAF Energy Systems for nickel-zinc battery system: Joplin, MO, ZAF Energy Systems, Inc. news release, October 1. (Accessed February 18, 2022, at https://www.businesswire.com/news/home/20191001005973/en/Air-Force-Contract-Awarded-ZAF-Energy-Systems.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
Nickel. Ch. in Mineral Commodity Summaries, annual.
Nickel. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Nickel. International Strategic Minerals Inventory Summary Report, Circular 930–D, 1985.
Nickel. Mineral Industry Surveys, monthly.
Nickel (Ni). Ch. In Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.

Other

International Nickel Study Group (Lisbon, Portugal).
Nickel. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Nickel Institute (Toronto).
Roskill Information Services Ltd.

TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons, nickel content, unless otherwise specified)

		2015	2016	2017	2018	2019
United States:						
Production, concentrate		27,200	24,100	22,100	17,600	13,500
Secondary recovery from purchased scrap:						
From ferrous scrap		110,000	125,000	127,000	117,000	106,000
From nonferrous scrap		5,590	5,790	5,740	5,690	4,820
Shipments of purchased scrap[2]		141,000	162,000	146,000	137,000 r	124,000
Exports:						
Ores and concentrates[3]		25,400	22,400	20,000	18,000	14,300
Primary[4]		9,610 r	10,300	11,000	9,780	12,800
Secondary		51,900	63,700	51,500	59,400 r	51,100
Imports for consumption:						
Ores and concentrates[3]		24	(5)	64	3	4
Primary[4]		130,000	111,000	150,000	144,000	119,000
Secondary		27,100	32,300	38,100	45,100	37,700
Consumption:						
Reported:						
Primary[4]		107,000	97,800	105,000	107,000	105,000
Secondary, purchased scrap		116,000	131,000	133,000	123,000	111,000
Total		223,000	229,000	238,000	230,000	216,000
Apparent, primary[4]		118,000	104,000	140,000	136,000	106,000
Apparent primary plus reported secondary[4]		234,000	235,000	273,000	259,000	217,000
Stocks, yearend:						
London Metal Exchange Ltd. (LME), U.S. warehouses		4,210	5,230	3,780	2,270	1,970
Consumer, primary[4]		10,600	6,370	6,550	6,780	6,860
Consumer, secondary		8,570	8,690	8,040	9,570	6,500
Total		23,400	20,300	18,400	18,600	15,300
Price:						
Cash, LME:						
Average annual	dollars per metric ton	11,831	9,594	10,403	13,114	13,903
Average annual	dollars per pound	5.367	4.352	4.719	5.948	6.306
Type 18-8 stainless-steel scrap:[6]						
Average annual	dollars per metric ton	1,073	897	1,035	1,108	1,113
Average annual	dollars per long ton	1,090	911	1,052	1,126	1,131
World, mine production		2,110,000	2,010,000	2,200,000 r	2,400,000	2,610,000

rRevised.
[1]Table includes data available through October 8, 2020. 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]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.
[5]Less than ½ unit.
[6]Source: S&P Global Platts Metals Week.

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

(Metric tons, nickel content)

	2018	2019
Kind of scrap:		
Aluminum-base	1,900	1,960
Copper-base	1,260	W
Ferrous-base[2]	117,000	106,000
Nickel-base	2,530	2,860 [3]
Total	123,000	111,000
Form of recovery:		
Aluminum-base alloys	1,900	1,960
Copper-base alloys	2,100	1,390
Ferrous alloys	118,000	107,000
Nickel-base alloys	902	880
Total	123,000	111,000

W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through October 8, 2020. 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.
[3]Includes copper, copper-nickel, and nickel-base scrap.

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

(Metric tons, nickel content)

Form	2018	2019
Primary:[2]		
Metal	89,600	88,000
Ferronickel	13,500	13,200
Oxide and oxide sinter[3]	202	189
Other[4]	3,440	3,380
Total	107,000	105,000
Secondary, scrap[5]	123,000	111,000
Grand total	230,000	216,000

[1]Table includes data available through October 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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.
[3]Includes chemical-grade oxide.
[4]Includes base-master alloys, nickel salts, and other forms of nickel not included above.
[5]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	2019			Grand total in 2018
	Total primary[2]	Secondary (scrap)	Grand total	
Chemicals and chemical uses[3]	2,460	W	2,460	2,830
Nickel alloys:				
Superalloys	31,600	W	31,600	27,300
Other[4]	15,600	4,030	19,600	20,600 r
Plating	7,590	--	7,590	7,240
Steel:				
Stainless and heat resistant	41,600	106,000	147,000	159,000
Alloys, excludes stainless	5,990	1,340	7,340	8,510
Grand total	105,000	111,000 [5]	216,000	230,000

rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.
[1]Table includes data available through October 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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.
[3]Includes batteries, catalysts, and ceramics.
[4]Includes cast iron; cemented carbides; coinage; copper-nickel and nickel-copper alloys; electrical, magnetic, expansion, and wear-resistant alloys; and powder alloys.
[5]Includes data indicated by symbol W.

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

(Metric tons, nickel content)

Form	2018	2019
Primary:[2]		
Metal	6,010	6,070
Ferronickel	W	322
Oxide and oxide sinter	43	50
Chemicals	W	W
Other	733	419
Total	6,780	6,860
Secondary, scrap	9,570	6,500
Grand total	16,300	13,400

W Withheld to avoid disclosing company proprietary data; included with "Primary: Other."
[1]Table includes data available through October 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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.

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

Class	2018 Quantity (metric tons, nickel content)	2018 Value (thousands)	2019 Quantity (metric tons, nickel content)	2019 Value (thousands)
Primary:[2]				
Unwrought:				
Cathodes, pellets, briquet, shot	1,460	$21,300	1,510	$22,100
Ferronickel	14	437	12	334
Powders and flakes	1,570	62,100	1,490	61,800
Metallurgical-grade oxide[3]	956	16,000	1,030	18,600
Chemicals:				
Catalysts[4]	4,700	362,000	7,640	510,000
Salts[5]	1,090	17,300	1,150	17,900
Total	9,780	479,000	12,800	630,000
Secondary:				
Stainless-steel scrap	40,900 r	319,000 r	35,200	348,000
Waste and scrap[6]	18,500 r	160,000 r	16,000	134,000
Total	59,400 r	479,000 r	51,100	483,000
Grand total	69,200 r	958,000 r	64,000	1,110,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	922	26,300 r	260	9,060
Sheets, strip, foil	392	14,200	337	9,910
Tubes and pipes	37	1,850	85	1,920
Total	1,350	42,300	682 r	20,900
Alloyed, gross weight:				
Unwrought alloyed ingot	5,490 r	192,000 r	7,040	236,000
Bars, rods, profiles, wire	27,100	854,000 r	27,800	915,000
Sheets, strip, foil	15,400	413,000	15,000	448,000
Tubes and pipes	2,760 r	247,000	2,110	261,000
Other alloyed articles	2,720 r	604,000	3,520	831,000
Total	53,500	2,310,000	55,400	2,690,000

rRevised.

[1]Table includes data available through August 18, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]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.

[3]Nickel content is assumed to be 77%.

[4]Typical catalyst is assumed to have a nickel content of 22%.

[5]Nickel contents are as follows: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts, assumed to be 22%.

[6]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]

	2019									
Country or locality[3]	Cathodes, pellets, and briquets (unwrought)	Powders and flakes	Ferronickel	Metallurgical-grade oxide[4]	Waste and scrap	Stainless-steel scrap	Chemicals	Total in 2019	Total in 2018	Wrought nickel in 2019[5]
Argentina	--	19	--	--	--	4	100	122	56	--
Australia	21	5	--	1	1,230	3	3	1,260	766	--
Belgium	10	7	--	14	60	119	499	710	1,050 r	(6)
Brazil	3	55	--	(6)	--	7	173	237	727	3
Canada	23	154	1	487	10,400	6,590	1,180	18,900	28,100 r	33
China	8	156	(6)	2	10	191	479	846	4,160	47
Denmark	--	(6)	--	--	--	5	341	346	179	--
Finland	--	(6)	--	--	1	33	535	568	118	--
Germany	6	298	(6)	32	254	47	242	879	492	69
Hong Kong	--	8	--	--	--	202	(6)	210	300	8
India	--	38	4	1	748	10,500	499	11,800	7,450	2
Indonesia	--	--	--	37	--	141	66	243	398	--
Italy	(6)	3	--	--	11	20	296	331	97	11
Japan	9	153	--	1	1,030	412	120	1,720	1,730	20
Korea, Republic of	(6)	74	--	--	19	742	678	1,510	890	9
Kuwait	56	--	--	--	--	--	1,410	1,470	259	--
Malaysia	--	--	--	1	9	702	221	933	541	1
Mexico	1,060	58	--	10	20	2,840	89	4,070	4,280	120
Netherlands	117	1	--	--	176	95	37	426	828	(6)
Pakistan	--	1	--	--	--	1,940	8	1,950	2,800	--
Russia	--	1	--	--	10	12	91	114	40	--
Saudi Arabia	--	4	--	--	--	41	296	342	136	(6)
Singapore	--	182	3	4	68	113	24	393	292	14
Spain	--	1	--	--	155	162	1	320	113	5
Sweden	--	41	--	--	641	70	70	821	899	--
Taiwan	7	15	3	--	81	9,230	185	9,520	7,790	5
Thailand	--	50	(6)	(6)	--	265	407	723	392	41
Turkey	177	13	--	2	--	5	61	258	72	--
United Arab Emirates	--	3	--	(6)	--	46	123	172	97	--
United Kingdom	--	49	(6)	412	875	6	25	1,370	1,020	3
Vietnam	--	7	--	--	--	403	235	645	1,760	11
Other[7]	7	95	(6)	28	133	283	286	833	1,370 r	113
Total	1,500	1,490	11	1,030	16,000	35,200	8,790	64,000	69,200 r	682 r

rRevised. -- Zero.

[1]Table includes data available through August 19, 2020. 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

[3]Countries and (or) localities listed were the leading export recipients in 2019 in terms of quantity (contained weight).

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

[5]Not included in total in 2019.

[6]Less than ½ unit.

[7]Includes countries and (or) localities with less than 100 metric tons total in 2019.

Source: U.S. Census Bureau.

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

Class	2018 Quantity (metric tons, nickel content)	2018 Value (thousands)	2019 Quantity (metric tons, nickel content)	2019 Value (thousands)
Primary:[2]				
Unwrought:				
Cathodes, pellets, briquets, shot	112,000	$1,490,000	97,400	$1,350,000
Ferronickel	21,700	299,000	11,900	153,000
Powders and flakes	6,800	140,000	6,370	129,000
Metallurgical-grade oxide[3]	319	8,010	237	4,530
Chemicals:				
Catalysts[4]	1,780	102,000	2,180	95,600
Salts[5]	1,280	22,100	876	17,400
Total	144,000	2,060,000	119,000	1,750,000
Secondary:				
Stainless-steel scrap	24,800	345,000	15,300	183,000
Waste and scrap[6]	20,300	318,000	22,400	328,000
Total	45,100	664,000 r	37,700	510,000
Grand total	189,000	2,720,000	157,000	2,260,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	264	6,290	299	7,910
Sheets, strip, foil	508	10,700	585	13,900
Tubes and pipes	65	1,800	118	3,690
Total	837	18,800	1,000	25,500
Alloyed, gross weight:				
Unwrought alloyed ingot	6,630 r	70,000 r	5,360	93,800
Bars, rods, profiles, wire	14,400	365,000	14,500	367,000
Sheets, strip, foil	4,340	91,000	5,440	121,000
Tubes and pipes	2,520	117,000 r	3,230	193,000
Other alloyed articles	6,480 r	308,000 r	8,030	389,000
Total	34,400 r	951,000 r	36,500	1,160,000

rRevised.

[1]Table includes data available through August 19, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]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.

[3]Nickel content from Australia, 90%; elsewhere, 77%.

[4]Typical catalyst is assumed to have a nickel content of 22%.

[5]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.

[6]Waste and scrap is assumed to be 50% nickel; stainless-steel scrap, 7.5% nickel.

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]

	2019									
Country or locality[3]	Cathodes, pellets, and briquets (unwrought)	Powders and flakes	Ferronickel	Metallurgical-grade oxide[4]	Waste and scrap	Stainless-steel scrap	Chemicals	Total in 2019	Total in 2018	Wrought nickel in 2019[5]
Australia	6,350	342	51	--	253	2	--	7,000	19,000	(6)
Belgium	--	107	--	--	36	1	253	397	595 r	1
Brazil	--	--	5,600	--	69	52	2	5,720	7,330	--
Canada	51,600	3,320	--	(6)	6,470	7,940	179	69,600	66,900	1
China	--	25	4	201	433	11	38	712	2,570 r	70
Denmark	(6)	--	--	--	--	--	452	453	155	--
Dominican Republic	--	--	2,220	--	--	11	--	2,230	5,640	--
Finland	12,300	680	--	--	24	--	81	13,100	11,300	--
France	--	12	--	--	900	3	603	1,520	1,550	186
Germany	--	67	--	--	1,060	(6)	329	1,450	1,500	569
Guatemala	--	--	767	--	--	3	--	770	3,120	--
India	--	63	--	--	104	6	222	395	523	33
Italy	18	(6)	--	--	511	1	13	544	492	4
Japan	3,000	76	--	(6)	1,620	49	321	5,070	5,220	6
Korea, Republic of	--	--	--	8	327	--	12	347	365	(6)
Madagascar	889	--	--	--	--	--	--	889	1,860	--
Mexico	--	2	--	--	2,020	7,010	--	9,030	12,300	1
Netherlands	--	--	100	--	61	(6)	148	309	3,310	1
New Caledonia	--	--	3,000	--	--	--	--	3,000	3,730 r	--
Norway	8,610	--	--	--	37	--	2	8,640	13,800	--
Philippines	--	--	--	--	2	--	102	104	134	--
Russia	10,700	433	57	(6)	1,980	2	(6)	13,200	11,000	--
Saudi Arabia	--	--	--	--	435	--	56	491	640	--
Singapore	--	--	--	--	907	(6)	26	933	609	--
South Africa	2,120	478	3	--	--	--	7	2,610	5,540	21
Spain	--	4	--	--	397	1	1	402	410	--
Switzerland	--	--	--	(6)	140	--	--	141	111	--
Taiwan	--	--	--	--	164	67	73	304	316	(6)
Turkey	(6)	--	--	--	265	--	--	265	236	--
United Kingdom	1,790	754	15	27	3,800	36	83	6,510	5,330 r	33
Other[7]	(6)	7	76	--	394	135	51	663	3,550 r	76
Total	97,400	6,370	11,900	237	22,400	15,300	3,050	157,000	189,000	1,000

rRevised. -- Zero.

[1]Table includes data available through August 25, 2020. 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; and 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 exporters to the United States in 2019 in terms of quantity (nickel content).

[4]Primarily oxide, rondelles, and sinter.

[5]Not included in total in 2019.

[6]Less than ½ unit.

[7]Includes 43 countries and (or) localities with less than 100 metric tons each in 2019.

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]	2015	2016	2017	2018	2019
Albania, laterite ore	6,680 r	3,952	4,939 r	4,204 r	2,830
Australia, undifferentiated or other	225,227	203,135	185,466 r	160,022 r	158,751
Botswana, sulfide ore, matte produced	16,789	14,273	--	--	--
Brazil, undifferentiated or other	94,800	86,400	76,800	74,400	60,600
Burma, laterite ore	23,000	20,000	20,000	21,000	20,000
Canada, sulfide ore, concentrate	225,351	230,210	206,354	177,867 r	181,410
China, undifferentiated or other	101,400	100,200	102,300 r	110,000 e	120,000 e
Colombia, laterite ore, dry	40,513	41,082	45,510	47,700	45,000
Cuba, laterite ore	53,800	51,600	52,800	52,200 r	49,200
Dominican Republic, laterite ore[e]	4,000	19,900	28,300	34,700	56,900
Finland, undifferentiated or other	9,383	20,654	34,641	43,572	38,530
Greece, laterite ore	19,610	19,431	19,073	17,925	13,655
Guatemala, laterite ore	56,400	45,900	53,700	39,200 r	36,300
Indonesia, laterite ore	129,600	204,000	355,000	606,000	853,000
Kosovo, laterite ore[e]	7,420	4,270	7,120	4,790 r	3,310
Madagascar, laterite ore, nickel-cobalt sulfide[e, 4]	55,000	49,000	42,000	39,000	39,000
Morocco, undifferentiated or other, nickel hydroxide	203	188	196	126 r	130 e
New Caledonia, laterite ore	193,199	204,207	215,382	216,225	208,185
Norway, undifferentiated or other	285	220	206	210	200
Papua New Guinea, laterite ore, nickel-cobalt hydroxide[5]	25,582	22,269	34,666	35,355	32,720
Philippines, laterite ore	415,021	300,506	339,377	344,966 r	323,325
Russia:					
Laterite ore	7,400	7,000 e	1,800 e	--	--
Sulfide ore, concentrate	269,310 r	251,840 r	265,500 r	272,300 r	278,700
South Africa, sulfide ore, concentrate	56,689	48,994	48,383	43,236	42,936
Spain, sulfide ore, concentrate	7,213	--	--	--	--
Turkey, laterite ore	9,900	10,680	17,000	17,000	16,600
United States, sulfide ore, concentrate	27,200	24,100	22,100	17,600	13,500
Venezuela, laterite ore	4,800	--	--	--	--
Vietnam, sulfide ore, concentrate	8,607	4,272	--	--	--
Zambia, sulfide ore, concentrate	--	--	--	--	3,000
Zimbabwe, sulfide ore, concentrate	16,109	17,743	16,617	17,850 r	16,593
Total	2,110,000	2,010,000	2,200,000 r	2,400,000	2,610,000
Of which:					
Laterite ore	1,050,000	1,000,000	1,240,000 r	1,480,000	1,700,000
Sulfide ore	627,000	592,000 r	559,000	529,000 r	536,000
Undifferentiated or other	431,000	411,000	400,000 r	388,000 r	378,000

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

[1]Table includes data available through November 17, 2020. 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]Often called mixed sulfide product or MSP.

[5]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	2015	2016	2017	2018	2019
Matte:					
Australia	44,268	38,247	36,812	11,400 r	16,900
Botswana	16,789	14,273	--	--	--
Canada[e, 3]	88,300	90,800	65,200	57,200	51,200
Finland	1,700 e	15,000 e	25,000	31,000	31,000 e
Indonesia[4]	81,177	77,581	76,807	74,806	71,025
New Caledonia	6,761	4,287	--	--	--
Russia[e, 5]	812	16,900	42,700	43,900	53,500
South Africa	400	--	--	--	--
Zimbabwe[6]	4,284	5,346	4,705	5,187	4,933
Total	245,000	262,000	251,000	224,000 r	229,000
Other:					
Cuba:[e]					
Ammoniacal liquor precipitate and unspecified	1,100 r	1,800 r	1,800 r	1,300 r	1,300
Nickel-cobalt sulfide[7]	36,700	34,800	35,200	34,800	37,000
New Caledonia, nickel-cobalt hydroxide[8]	9,686	7,269	6,525	6,723	6,483
Papua New Guinea, nickel-cobalt hydroxide[8]	25,582	22,269	34,666	35,355	32,720
Philippines, nickel-cobalt sulfide[7]	51,733	48,371	50,553	48,633	51,144
Turkey, nickel-cobalt hydroxide[8]	--	1,790	4,000	5,001	2,175
Total	125,000 r	116,000 r	133,000 r	132,000 r	131,000
Grand total	369,000	379,000 r	384,000 r	355,000 r	359,000

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

[1]Table includes data available through March 24, 2021. 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]Nickel content of matte and metallurgical-grade nickel oxide as reported by the Global Trade Atlas 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%.

[4]Represents the nickel output of the Sorowako smelter. The Sorowako matte was shipped to Japan for further processing and contains on average 78% nickel.

[5]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.

[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]	2015	2016	2017	2018	2019
Australia:					
Metal	132,074	117,920	108,500	114,517 r	106,470
Unspecified[4]	20,904	2,600	--	--	--
Total	152,978	120,520	108,500	114,517 r	106,470
Austria, ferronickel	1,000	1,000	1,000	1,000	1,000
Brazil:					
Ferronickel	54,700	68,600	68,803 r	65,254 r	54,221
Metal	22,650	--	--	--	--
Total	77,350	68,600	68,803 r	65,254 r	54,221
Burma, ferronickel[5]	15,600 e	16,800	16,200	15,900 r, e	15,500
Canada, unspecified	149,716	158,299	154,759 r	137,411 r	124,736
China:[6]					
Chemicals	18,891	29,100	39,900	45,200	41,300
Ferronickel, nickel pig iron	385,035	374,745	411,462	476,040	600,340
Metal	236,700	221,700	202,900 r	191,100 r	185,000 e
Total	640,626	625,545	654,262 r	712,340 r	827,000
Colombia, ferronickel	36,671	37,092	40,600	43,100	40,600
Cuba, oxide sinter, including oxides[7]	14,667	15,006	15,751	14,670 r	15,000 e
Dominican Republic, ferronickel	--	9,913	15,632	19,214	28,450
Finland:					
Chemicals	7,129	8,048	8,358	10,330	10,608
Metal	36,350	45,606	51,342	50,435	51,792
Total	43,479	53,654	59,700	60,765	62,400
France, unspecified[8]	6,533	4,639	2,329	3,667	6,947
Greece, ferronickel	17,113	17,071	16,781	15,720	11,974
Guatemala, ferronickel	10,826	8,688	12,416	14,688	20,323
Indonesia:					
Ferronickel	17,211	20,293	21,762	24,868	25,713
Ferronickel, nickel pig iron[e]	27,200	75,900	74,800	73,300	179,000
Total	44,400	96,200	96,600	98,200	205,000
Japan:					
Chemicals	10,045	11,153	16,773	15,624	16,132
Ferronickel[e]	73,400 r	61,700 r	57,800 r	62,900 r	58,000
Metal	64,068	63,132	61,377	57,517	58,777
Oxide sinter	45,300 r	55,500 r	51,100 r	50,700 r	50,000 e
Total	193,000	191,000	187,000	187,000	183,000
Korea, Republic of, ferronickel[9]	39,005	45,600	47,400	45,631 r	46,000
Kosovo, ferronickel	11,301	2,540	7,100	5,700	3,900 e
Macedonia, ferronickel	17,699	10,603	7,175	10,100	15,202
Madagascar, metal	47,271	42,105	35,474	33,183	33,733
Morocco, chemicals, nickel-hydroxide	203	188	196	126 r	125 e
New Caledonia:					
Ferronickel	56,486	67,518	73,219	82,114	70,654
Oxide sinter	21,044	28,465	30,875	25,800	17,267
Total	77,530	95,983	104,094	107,914	87,921
Norway, metal	91,220	92,700	86,500	90,800	92,100
Russia:					
Chemicals	2,900	2,400 e	--	--	--
Metal	231,200	188,700	157,396	158,005	166,265
Total	234,100	191,000	157,396	158,005	166,265
South Africa:					
Chemicals[10]	5,300 e	4,743	4,966	5,281 r	4,600 e
Metal	41,910	42,332	42,362	39,500 r	39,100
Total	47,200	47,075	47,328	44,781 r	43,700
Taiwan	(9)	(9)	(9)	(9)	(9)
Ukraine, ferronickel[11]	18,000 e	18,100	15,300	15,807	14,200

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]	2015	2016	2017	2018	2019
United Kingdom, metal	38,804	45,194	38,052 r	41,220 r	35,000 e
Venezuela, ferronickel	4,000	--	--	--	--
Zimbabwe, metal[12]	617	--	--	--	--
Grand total	2,030,000	2,020,000	2,000,000 r	2,060,000 r	2,240,000
Of which:					
Chemicals	44,500	55,600	70,200	76,600	72,800
Ferronickel	785,000 r	836,000 r	887,000 r	971,000 r	1,190,000
Metal	943,000	859,000	784,000 r	776,000 r	768,000
Oxide sinter	81,000 r	99,000 r	97,700 r	91,200 r	82,300
Unspecified	177,000	166,000	157,000 r	141,000 r	132,000

eEstimated. rRevised. -- Zero.

[1]Table includes data available through March 24, 2021. 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 such as nickel chemicals and salts, ferronickel, nickel metal in various forms, nickel oxide sinter, and nickel pig iron (a form of ferronickel with nickel content typically less than 15%). The USGS 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. Several countries produced nickel-containing matte and other intermediates, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries that produced intermediate products for export are listed in table 11.

[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.

[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.

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

[8]Includes metal and nickel chloride.

[9]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.

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

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

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