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NICKEL [ADVANCE RELEASE]

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Nickel

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Global consumption of nickel continued to increase in 2014 despite low demand in Germany, Italy, the Republic of Korea, and Russia. The overall growth was accounted for largely by increased production of austenitic stainless steel and superalloys in China and to a lesser degree in India and North America. World mine production of nickel declined to 2.26 million metric tons (Mt) of contained nickel in 2014 after reaching an alltime high of 2.79 Mt (revised) in 2013 (table 10). The Indonesian export ban on lateritic direct shipping ore (DSO) was responsible for the bulk of the decline. The London Metal Exchange Ltd. (LME) average monthly cash price for nickel metal peaked in May 2014 at $19,434 per metric ton, but then began an extended decline. The LME average monthly cash price ended the year at $15,914 per metric ton and averaged $16,865 per metric ton for 2014 (table 1). Daily stocks of nickel metal continued to increase in LME-sanctioned warehouses throughout 2014 and ended the year at 414,900 metric tons (t)—an alltime high as of 2014.

Austenitic (nickel-bearing) stainless steel accounted for about 66% of global primary nickel (nickel produced from the refining of mined material rather than that recovered from recycled scrap) consumption. China was the leading producer of austenitic stainless steel, accounting for about 55% of world output, as well as the leading consumer of primary nickel. World production of stainless and heat-resisting steel reached a record high of 41.7 Mt in 2014, but the growth was uneven geographically (ERAMET Group, 2015, p. 3–7, 15–16; International Stainless Steel Forum, 2015a). On a global basis, nonferrous alloys accounted for about 10% of primary nickel use; electroplating and other surface finishing, 9%; alloy steels other than stainless, 8%; batteries, catalysts, and specialty chemicals, 4%; and foundry products, 3% (Nickel Institute, 2016, p. 14).

Reported nickel consumption (primary plus secondary) in the United States in 2014 increased slightly to 209,000 t compared with that of 2013 (table 1). U.S. apparent consumption of primary nickel was 151,000 t, or about 8% of world consumption, based on the 1.86 Mt reported by the International Nickel Study Group (INSG). Stainless steel production accounted for 43% of U.S. primary consumption, a reflection of the large number of specialty metal industries and a readily available supply of stainless steel scrap (table 4). U.S. industry reported melting 94,200 t of nickel contained in scrap, a slight increase from 93,100 t (revised) in 2013 (table 3) (International Nickel Study Group, 2015, p. A–1).

Legislation and Government Programs

Projects Supported by the U.S. Department of Energy (DOE).—The DOE has focused efforts on promoting five clean energy technologies: electric vehicles (EVs), light-emitting diodes (LEDs), rooftop solar photovoltaics (PVs), utility-scale solar PVs, and wind turbines. The DOE also supported four other emerging technologies—3D printing, energy management systems, fuel cells, and grid-connected batteries—as well as greenfield geothermal projects.

Some of the DOE-supported projects had applications for both transportation and power generation. One example was the development of improved stationary and portable fuel cell power systems. Like a battery, a fuel cell has an anode and a cathode with an electrolyte sandwiched between the two terminals. The molten carbonate Direct FuelCell® powerplants developed by FuelCell Energy, Inc. (Danbury, CT) use porous nickel catalysts for both the anode and cathode (Leo, undated).

U.S. Coinage.—The U.S. Mint increased coin production in 2014 for the fifth consecutive year to meet increasing demand from a recovering economy. The Mint was still operating at a reduced level when compared with the period from 2004 through 2007, however. The nickel-bearing coinage minted in 2014 contained 2,700 t of nickel in the form of either cupronickel or manganese brass alloy. In 2014, the Mint produced a total of 1,206 million Jefferson nickels (25% nickel by weight), down from 1,223 million in 2013. Production of Roosevelt dimes (8.33% nickel), in contrast, increased to 2,303 million from 2,112 million (U.S. Mint, undated a, b).

Production

The United States produced 4,300 t of nickel in concentrate in 2014 (table 1). All of the ore used to produce the concentrate came from the Eagle Mine in the Upper Peninsula of Michigan. Limited quantities of byproduct nickel were recovered at some copper and precious metal refineries, particularly the Stillwater Mining Co. (Billings, MT) base metals refinery. Leading processors of nickel containing scrap included International Metals Reclamation Co. Inc.'s secondary smelter in Ellwood City, PA, that processed nickel-containing scrap and Gulf Chemical and Metallurgical Corp.'s facility in Freeport, TX, that processed spent catalysts from petroleum refineries. The refinery recovery data are included with the scrap statistics in tables 2 through 5.

No ferronickel was produced from ores in the United States in 2014. Almost all U.S. ferronickel exports were either reexports or material upgraded for special purposes.

Michigan.—On September 23, 2014, Lundin Mining Corp. (Toronto, Ontario, Canada) began commercial production at the Humboldt mill in Humboldt Township. Ore was trucked from Lundin's nearby Eagle Mine, located southwest of Big Bay in Michigamme Township, which began operation earlier in 2014. The mill produced separate concentrates of copper and nickel sulfides. The two sulfide concentrates were railed on a dedicated spur from Humboldt to the Canadian National Railway line, and then to smelters in Canada or to ports for shipment overseas.

The mine was expected to produce an average of 17,000 metric tons per year (t/yr) of nickel and 17,000 t/yr of copper in concentrates during the first 8 years of its life (Welch and others, 2014, p. 26, 29–30, 36; Lundin Mining Corp., 2015, p. 20, 151).

Minnesota.—PolyMet Mining Corp. (Toronto, Ontario, Canada) was waiting for approval from the State of Minnesota to begin mining the copper, nickel, and platinum-group-element (PGE) Northmet deposit, located 9.7 kilometers (km) [6 miles (mi)] south of the town of Babbitt in St. Louis County. By yearend 2014, the Minnesota Department of Natural Resources had completed most of the final NorthMet Environmental Impact Statement and was planning to submit the document for review to the U.S. Environmental Protection Agency and other cooperating agencies by the summer of 2015.

Beginning in October 2008, PolyMet entered into a series of financial agreements with Glencore AG (a wholly owned subsidiary of Glencore plc of Baar, Switzerland). By yearend 2014, Glencore AG owned 28.5% of the common stock issued by the mining corporation. Glencore AG also agreed to market all of PolyMet's concentrates, other intermediate products, and metals produced during the first 5 years of the Hoyt Lakes operation (Newby and Knudson, 2015, p. 3, 5, 11–14; PolyMet Mining Corp., 2015, p. 31).

Duluth Metals Ltd. (Toronto, Ontario, Canada), Teck American Inc. (Spokane, WA), and Twin Metals Minnesota LLC (St. Paul, MN, a joint venture of Antofagasta plc and Duluth Metals) each continued to actively evaluate disseminated sulfide deposits in the Duluth Complex, with a focus on the Mesaba-Birch Lake-Nokomis area (Minnesota Minerals Coordinating Committee, 2014). In August 2014, Duluth Metals released highlights from a draft National Instrument 43–101 Technical Report on the Twin Metals Minnesota project, 14 km (9 mi) southeast of Ely. The report supported earlier claims that the Duluth Complex hosts one of the world's largest undeveloped accumulations of copper-nickel sulfides and PGEs. Measured resources at the Maturi deposit consist of 1.8 Mt of copper and 544,000 t of nickel, based on a copper cutoff grade of 0.3%. Combined indicated resources at the Birch Lake, Maturi, and Maturi Southwest deposits include an additional 5.2 Mt of copper and 1.7 Mt of nickel (Duluth Metals Ltd., 2013, p. 5–9; Barber and others, 2014).

Oregon.—Red Flat Nickel Corp. (Portland, OR) continued to explore for nickel in the Rogue River-Siskiyou National Forest. The proposed drilling program, dubbed Cleopatra, would initially focus on an area near Baldface Creek, about 13 km (8 mi) east-southeast of Gold Beach in Curry County (Fattig, 2013). In June, Red Flat Nickel applied to the Oregon Water Resources Department for a license to use water from an unnamed, nearby creek for mineral exploration drilling. On September 30, the department denied the application largely on the basis of a site visit and comments received from the Oregon Department of Environmental Quality. Red Flat Nickel still had the option of hauling in drilling water, a practice occasionally used in the more arid southwestern States (Oregon Water Resources Department, 2014).

Byproduct Smelter and Refinery Production.—In 2014, Stillwater Mining Co. shipped 660 t of nickel in crystalline sulfate, up from 612 t in 2013. Stillwater mined PGEs from the J-M Reef in Montana's Beartooth Mountains. Concentrates from the company's two mills (East Boulder and Nye) were trucked to Stillwater's smelting and refining complex at Columbus, MT, where a PGE filter cake and byproduct crystalline nickel sulfate containing minor amounts of cobalt were produced. Spent PGE catalysts were added to the sulfide concentrates to sweeten the smelter feed. The additions were primarily automotive exhaust, chemical processing catalysts, and petroleum refining. The nickel and copper sulfides that occur naturally in the concentrates act as a metallurgical collector in the smelter furnace and facilitate extraction of the PGEs from the recycled materials. In 2014, the Graham Creek development area at the East Boulder Mine came online, enabling the adjoining mill to increase its output of concentrate (Stillwater Mining Co., 2015, p. 7–8, 11, 19–20, 50–52, 58–60).

Secondary Production.—The International Metals Reclamation Co. Inc. (INMETCO) [owned by Horsehead Holding Corp. (Pittsburgh, PA)] 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, grindings, mill scale, and swarf generated during the manufacturing of stainless steel. The complex also accepted filter cakes, plating solutions, sludges, and spent rechargeable batteries. INMETCO was the only facility in North America that thermally processed spent nickel-cadmium batteries and also processed nickel-iron (Edison-type) batteries and nickel-metal hydride (NiMH) batteries (Horsehead Holding Corp., 2015, p. 1–6, 13–15, 36, 41, 52).

Gulf Chemical & Metallurgical Corp. (Freeport, TX) [owned by ERAMET Group (Paris, France)] was one of a limited number of companies worldwide that processed spent catalysts from petroleum refineries. The Freeport facility treated nickel-molybdenum and cobalt-molybdenum hydrotreating catalysts that had been "poisoned" by nickel and vanadium contained in the crude oil. Gulf Chemical first roasted and leached the spent catalysts to recover the molybdenum and vanadium. The nickel-and-alumina residue was then converted to a nickel-cobalt-molybdenum alloy in a direct-current electric arc furnace. Catalyst processing was expected to increase in North America as the result of the rapid increase in natural gas and oil production from shale oil and other tightly locked resources between 2008 and 2013 (Gulf Chemical & Metallurgical Corp., 2013a, b, 2014; Sieminski, 2014).

Consumption

Apparent primary nickel consumption in the United States increased to 151,000 t in 2014 from 110,000 t in 2013 (table 1). The estimated value of apparent primary nickel consumption was $2.55 billion, an increase from $1.65 billion in 2013, owing in part to a 12% increase in the LME cash price. The U.S. steel industry consumed 13,300 t (85%) of ferronickel in 2014, of which more than 99% was used in stainless, heat-resistant, or specialty alloy steels (table 4).

Stainless Steel and Low-Alloy Steels.—In 2014, stainless steel producers accounted for 43% of reported primary nickel consumption in the United States (table 4) and 60% of primary consumption in the world (International Nickel Study Group, 2015, p. A–1). Alloy steels—other than stainless—accounted for an additional 3% of U.S. primary nickel use. Production of raw stainless steel and heat-resisting steel in the United States totaled 2.63 Mt in 2014, up by 18% from 2.24 Mt in 2013. Nickel-bearing grades accounted for 1.87 Mt, or 71% of total stainless steel production (American Iron and Steel Institute, 2015a, p. 70–71; 2015b). North American Stainless, the Kentucky subsidiary of Acerinox, S.A., was the leading U.S. producer of flat-rolled stainless steel in 2014 and had more than 1,350 employees (Shepherd, 2015).

Outokumpu Stainless USA, LLC continued to ramp up production at its integrated stainless steel mill at Calvert, AL. The meltshop at Calvert was designed to produce up to 1 million metric tons per year (Mt/yr) of stainless steel slabs. Both austenitic and ferritic grades were produced. The meltshop had a 160-t-capacity electric arc furnace, a 180-t-capacity argon oxygen decarburization converter, and a continuous caster. The meltshop was supplying slab to both the Calvert cold-rolling mill and Outokumpu's cold-rolling mill in San Luis Potosi, Mexico. The Calvert facility was the only plant in the United States that was designed to make 72-inch-wide sheet and plate suitable for seamless large tanks and other containers for the transport and petrochemical industries. In the second half of 2014, Outokumpu USA began experiencing technical problems with its cold-rolling lines at Calvert, but all of the lines were back in production by early 2015 (Outokumpu Oyj, 2015, p. 3, 7–19).

Superalloys and Related Nickel-Base Alloys.—On January 27, 2014, Carpenter Technology Corp. (Wyomissing, PA) formally opened its $518 million metals plant in Tanner, Limestone County, AL. The Alabama plant was designed to produce 27,000 t/yr of ultrapremium alloys and would focus on products for aerospace engines, critical energy applications, and medical devices. The facility was initially producing 4- to 18-inch alloy round bar from high-purity ingots shipped from the company's vacuum induction melting furnaces at Latrobe and Reading, PA. Carpenter was also in the process of constructing a superalloy powder production facility adjacent to the Tanner facility that was expected to begin production in late 2015 (Carpenter Technology Corp., 2013, 2014; Berry, 2014).

Nickel-Containing Batteries and Hybrid Electric Vehicles.—U.S. demand for nickel in rechargeable batteries continued to increase. In 2014, many of the non-plug-in hybrid electric vehicles on U.S. highways still used NiMH batteries, which were commercially introduced in 1989. However, the rechargeable battery market remained highly competitive, and a variety of lithium-ion and lithium-iron-phosphate batteries were making inroads against the standard NiMH technology. In 2014, all of the electric vehicles manufactured by Ford Motor Co. (Dearborn, MI) were equipped with lithium-ion batteries. The lithium-ion batteries were generally 25% to 30% smaller and 50% lighter than their NiMH counterparts. The hybrid battery in the 2015 Ford C-MAX incorporates lithium nickel-manganese-cobalt oxide (or NMC) technology, and is used to power the electrical system as well as propel the vehicle at low speeds in stop-and-go traffic. The U.S. automotive industry was working with emergency services, scrap buyers, and vehicle dismantlers to ensure that the high-voltage batteries were safely recycled at end of life (Ford Motor Co., 2014; Hybrid Shop, The, 2015).

In June 2014, Tesla Motors Inc. (Palo Alto, CA) broke ground east of Sparks, NV, on a $5 billion factory designed to produce lithium-ion batteries for electric vehicles. The factory was named the "Gigafactory" because it was planned to have an annual battery production capacity of 35 gigawatt hours (GWh). The Gigafactory was expected to begin commercial production of battery cells by the end of 2016 and reach full capacity by 2018. The Gigafactory was also expected to produce stationary battery packs designed to (1) improve the robustness of the U.S. and foreign electrical grids, and (2) provide a backup supply of power for both factories and residences (Tesla Motors Inc., undated a, b).

Stocks

Increased global consumption of nickel failed to keep pace with production throughout the second half of 2014. Stocks of nickel in LME-approved warehouses continued to build up throughout 2014. By December 31, 2014, LME stocks had risen to 414,900 t. Almost one-half of the material—203,316 t, or 49%, was stored at Johor, Malaysia. An additional 135,276 t, or 33%, was held in Rotterdam, the Netherlands—the traditional LME storage point for the European Union and Russia. All stocks in LME warehouses were Class I material (refined products with a nickel content of 99% or greater) (London Metal Exchange Ltd., 2014).

Data collected by the International Nickel Study Group (2015, p. A1–A2, A7) indicated that, at yearend 2014, world nickel producers (excluding those in Austria, China, Kosovo, Macedonia, and the Ural region of Russia) held an additional 92,100 t of primary nickel stocks. About 72%, or 66,400 t, was Class I material, which included, in order of decreasing quantity, electrolytic cathode, briquets, pellets, powder, and rondelles. The remaining 28%, or 25,700 t, was Class II material (products with nickel content less than 99%), which included ferronickel, nickel pig iron (NPI) from China, oxide sinter, and East Asian utility nickel. At yearend 2014, U.S. consumer stocks of primary nickel totaled 11,800 t, slightly less than the 12,000 t held at yearend 2013 (tables 1, 5).

Prices

In 2014, nickel production from newly commissioned smelters and refineries continued to increase more rapidly than global consumption. The LME monthly mean of the cash buyer and settlement prices temporarily peaked in May at $19,434 per metric ton ($8.815 per pound), but then declined, dropping to $15,914 per ton ($7.219 per pound) in December as stocks built up continuously in warehouses sanctioned by the LME or the Shanghai Futures Exchange. The average annual LME price for 2014 was $16,865 per ton ($7.650 per pound)—12% greater than the 2013 average.

World Review

Although mine production in many countries increased in 2014, global mine production decreased by 18% to 2.26 Mt from a record-high 2.79 Mt in 2013 as the result of the Government of Indonesia halting all exports of DSO to overseas producers of ferronickel and NPI (see the section "Indonesia"). World use of primary nickel was 1.87 Mt in 2014—an alltime high for the fifth consecutive year—and was 5% greater than the previous high of 1.78 Mt in 2013. Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk (Antam) (Indonesia) had previously been a top producer of large tonnages of DSO for the Chinese NPI industry prior to the Indonesian embargo. However, in 2014, Chinese nickel demand was partially met by increased ore exports from the Philippines. Chinese producers of NPI were able to keep their production at existing levels by blending the Philippine ore with previously stockpiled Indonesian ore (International Nickel Study Group, 2015, p. A–1, A–7).

Australia.—Australia was the second-ranked nickel-producing country in the world in terms of mine output and ranked fourth in plant output (tables 10, 12). Seven companies in Western Australia reported producing salable nickel in 2014. Three of the eight trucked sulfide ore to BHP Billiton Ltd.'s concentrator at Kambalda for further processing [Department of Mines and Petroleum (Western Australia), 2015, p. 39; Evans and Lucas, 2015].

Laterite Operations.—The Palmer Nickel and Cobalt Refinery (formerly named Yabulu) processed laterite ores and intermediate products purchased from independent mining operations in New Caledonia and the Philippines. Imports of ore from Indonesia were minimal in 2014 as a result of the export ban imposed by the Government of Indonesia. In 2014, Palmer produced about 35,000 t of nickel, mostly in the form of compacts (a product similar to rondelles) averaging 98.5% nickel or greater. Other products included nickel carbonate, specialty nickel oxide, and nickel oxide sinter (Queensland Nickel Pty Ltd., undated).

Glencore's Murrin Murrin complex east of Lenora, Western Australia, used sulfuric acid to leach nickel and cobalt from lateritic ores in high-temperature, high-pressure autoclaves. The mining and processing operation produced 36,400 t of nickel metal, a slight increase from that produced in 2013 and a record high for the complex (Glencore plc, 2015, p. 53, 73).

First Quantum Minerals Ltd. (Vancouver, British Columbia, Canada) processed 3.1 Mt of beneficiated lateritic ore averaging 1.5% nickel at its Ravensthorpe complex northeast of Hopetoun in Western Australia. This was the third full year of commercial operation for First Quantum's Australian subsidiary. In December, First Quantum was forced to shut down its secondary processing circuit after an atmospheric leach tank ruptured. However, the primary high-pressure circuit was still operable, permitting Ravensthorpe to run temporarily at reduced capacity until the tank could be replaced. In 2014, Ravensthorpe produced 36,445 t of nickel contained in a mixed nickel-cobalt-hydroxide intermediate (Evans and Lucas, 2015; First Quantum Minerals Ltd., 2016, p. 12, 22).

Sulfide Operations.—In 2014, Nickel West, a subsidiary of BHP Billiton, produced 60,600 t of metal briquets and powder at its Kwinana refinery in Western Australia. Matte produced at the company's Kalgoorlie smelter was the principal feedstock. Kwinana also produced several intermediate products, including ammonium sulfate, cobalt-nickel sulfide, and copper sulfide. The Kalgoorlie smelter produced an additional 25,100 t of nickel in finished matte (65% nickel) for export. Lower production was partially attributed to the closure of the Perseverance Mine following a seismic event in late 2013. The feed for the Kalgoorlie smelter was supplied by concentrate from the Kambalda, Leinster, and Mount Keith facilities. The ore at Leinster and Mount Keith was supplied by company mines. The ore at Kambalda was sourced through third-party toll and purchase agreements (BHP Billiton Ltd., 2014a, p. 28; 2014b, p. 67–68, 160–165, 171; 2015, p. 10, 26).

Poseidon Nickel Ltd. (Perth, Western Australia) was preparing to recommission the Mt. Windarra underground mine in the North Eastern Goldfields district, 260 km northeast of Kalgoorlie, Western Australia. The mine had been in operation from 1974 to 1993. In October 2014, Poseidon agreed to truck ore from Mt. Windarra to BHP's concentrator at Leinster. The Mt. Windarra ore replaced ore that had previously been supplied by BHP's Perseverance Mine (Poseidon Nickel Ltd., 2014, p. 7, 12–17).

In 2014, OJSC MMC Norilsk Nickel (Moscow, Russia) sold or agreed to sell its remaining nickel mines and processing facilities in Western Australia—the Black Swan, Lake Johnston, and Silver Swan facilities were sold to Poseidon Nickel Ltd., and the Avalon and Cawse facilities were sold to Wingstar Investments Pty Ltd. (Perth, Western Australia). Norilsk Nickel, however, decided to retain its development license for the Honeymoon Well deposit 35 km southeast of Wiluna, Western Australia, close to the Goldfields Highway (OJSC MMC Norilsk Nickel, 2015, p. 14, 19, 43).

Brazil.—Seven companies mined nickel ore in Brazil—Anglo American Níquel Brasil Limitada, Cia. Nickel do Brasil, Grupo Votorantim, Mineradora Comercial Lillian Ltda., Mirabela Nickel Ltd., Prometálica Mineração Centro Oeste S.A., and Vale S.A. The seven companies extracted a total of 13.9 Mt of ore containing 167,000 t of nickel [Departamento Nacional de Produção Mineral (Brazil), 2015, p. 90–91].

Anglo American's new $1.9 billion Barro Alto mining and smelting complex in Goias State produced 28,300 t of nickel in ferronickel in 2014, 13% more than the 25,100-t output of 2013. The smelter had been expected to reach a design capacity of 41,000 t/yr of nickel in ferronickel in 2013. However, temporary repairs had to be made to one of two electric furnaces after hot metal broke through a sidewall, forcing Anglo American to scale back production. Company management subsequently decided to rebuild both furnaces in order to correct inherent design problems discovered during the partial rampup. Anglo American shut down one furnace in October 2014 for 7 months for rebuilding and upgrading and planned to upgrade the other furnace in the second half of 2015. Barro Alto was expected to produce 36,000 t of nickel in ferronickel in 2016 as a result of the furnace improvements (Spinetto, 2013; Anglo American plc, 2015a, p. 58, 206; 2015b).

Vale S.A. operated only one of the two furnaces at its new Onça Puma ferronickel smelting complex in Ourilandia do Norte, Para State. Vale S.A. was forced to suspend operations

in June 2012 after both furnaces were damaged during rampup, but subsequently rebuilt one furnace. The nominal capacity of the single-line operation was 25,000 t/yr of nickel in ferronickel. In 2014, Onça Puma produced a total of 21,400 t of nickel in ferronickel. The mining part of the operation delivered 1.36 Mt of lateritic ore averaging 2.19% nickel to the furnace yard (Vale S.A., 2013; 2015, p. 38–40, 67).

Because of a transformer malfunction at Votorantim Metais Níquel S.A.'s Fortaleza smelter in Minas Gerais in late 2013, the furnace reportedly was idle in 2014. Votorantim declared force majeure and was unable to fulfill its offtake deal with Mirabela Nickel Ltd. (Perth, Western Australia). Under the terms of the agreement, Mirabela formerly trucked sulfide concentrate produced at its Santa Rita Mine near Ipiau, Bahia State, to the Fortaleza smelter for processing. In 2014, Mirabela instead exported 4,294 t of nickel contained in concentrate (36% of production) to Norilsk Nickel Harjavalta Oy's smelter in Finland and sold 4,919 t (41% of production) in country to an international trading house. Total production at the Santa Rita Mine was 12,047 t of nickel in concentrate, a decrease from 15,626 t in 2013 (Klinger, 2013; Reuters, 2013; Mirabela Nickel Ltd., 2015, p. 11–15, 23).

Canada.—Four Provinces had active nickel mines in 2014—Manitoba, Newfoundland and Labrador, Ontario, and Quebec—with a total output of 235,000 t of contained nickel (table 10). In addition, companies were evaluating a variety of nickel deposits in all but two of the remaining nine Provinces or Territories.

Manitoba.—Vale Canada Ltd.'s operation at Thompson processed 26,100 t of refined nickel in 2014 from ores extracted from the Birchtree and Thompson Mines. The Thompson Mine processed 1.18 Mt of ore grading 1.95% nickel, whereas the Birchtree Mine processed 545,000 t grading 1.39% nickel (Vale S.A., 2015, p. 42–43). The Thompson operation also smelted concentrates shipped from Vale Canada's mining operation near Voisey's Bay in northern Newfoundland and Labrador.

In September, Vale Canada reached an agreement in principle with the Federal Government to allow the 53-year-old smelter in Thompson to continue operating until 2019. The agreement postponed Vale Canada's plans to phase out nickel smelting and refining at Thompson by yearend 2015.

Newfoundland and Labrador.—In July, Vale Canada began producing nickel metal rounds (a form of electrolytic nickel) at its new $4.25 billion Long Harbour hydrometallurgical processing plant on Placentia Bay, Newfoundland and Labrador. The state-of-the-art plant, located on the northeastern shore of the bay, had been under construction since April 2009. The first rounds were produced using sulfide concentrates from the Ovoid Mine near Voisey's Bay and matte from PT Vale Indonesia Tbk as feed. The button-shaped pieces of nickel metal were 25 to 29 millimeters (mm) in diameter and 5 to 6 mm in thickness. Each round weighed 26 to 32 grams and contained a minimum of 99.8% nickel by weight (Roberts, 2014; Vale Canada Ltd., 2016).

Ontario.—Vale Canada's Ontario Division produced 64,300 t of refined nickel from its own ores in 2014, down from 69,400 t in 2013. The Ontario Division had seven mines operating in 2014. Some of the 64,300 t was recovered from intermediate nickel oxide at the division's Clydach refinery in the United Kingdom. The division's new Totten Mine, 40 km west of Copper Cliff, became fully operational in February and produced 303,000 t of ore averaging 1.50% nickel and 1.98% copper. Vale Canada spent $760 million renovating, enlarging, and modernizing the original Totten Mine. The main shaft of the original mine had been allowed to partially flood in 1976. The original head frame and hoist plant were demolished shortly after dewatering and construction began in 2007. The company also resumed work on its feasibility study of the Copper Cliff Deep project (Martell and Rocha, 2014; Vale S.A., 2015, p. 35, 39–40; Mining-technology.com, undated).

Quebec.—Glencore's Raglan operation had four underground mines operating at the end of 2014—Katinniq, Kikialik, Mine 2, and Qakimajurq. In November 2014, Glencore launched the Sivumut Project, which would allow mining to begin east of Katinniq, but required a new environmental and social impact assessment with input from the Kangiqsujuaq, Salluit, and other Nunavimmiut communities. Subject to approval of Phase II of the Sivumut Project, two new underground mines—the Donaldson Mine and Mine 14—were planned to be developed, allowing mining to continue until 2032. Three additional underground mines—Boundary, Mine 8, and West Boundary—could be brought online in Phase III, conceivably extending mining until 2041 (SNC-Lavalin Inc., 2014b, p. 4–8; Raglan Mine, 2015).

Finland.—In 2014, Norilsk Nickel Harjavalta Oy produced 42,600 t of commercial nickel. The total included 22,600 t of briquets, 13,900 t of cathodes, 5,800 t (gross weight) of nickel salt, and the remainder was nickel solution and nickel metal powder. Feedstocks included sulfide concentrates from the Kevitsa Mine (Finland), Mirabela (Brazil), the Nkomati Mine (South Africa), the Talvivaara Mining Co. Plc (Finland), and Titania A/S (Norway). The concentrates were first converted to matte at the neighboring smelter of Boliden Harjavalta Oy as part of a tolling agreement. The Boliden mattes were then transferred to Norilsk's refinery and processed together with high-grade mattes from Botswana and Brazil (OJSC MMC Norilsk Nickel, 2015, p. 42–43, 52, 56–57).

Guatemala.—At yearend 2014, two companies were mining lateritic ores in Guatemala—Cunico Resources NV (Amsterdam, Netherlands) and the Solway Investment Group, GmbH (Zug, Switzerland). In August, Solway commissioned its newly built powerplant and metal processing facility (ProNiCo) in the Department of Izabal. Solway invested more than $600 million in the Fenix ferronickel project since acquiring the operation in 2011. The Fenix operation had been on care-and-maintenance status since 1980 and included a brownfield laterite mine. The mining and metallurgical complex is located 6 km west of El Estor on the north shore of Lake Izabal. Solway had a 98.2% interest in the operation; the Government of Guatemala owned the remaining 1.8%. The 25-year renewable exploitation license was issued in 2006 to Compañía Guatemalteca De Níquel S.A. (CGN), which later became the local subsidiary of Solway. The ferronickel produced was exported to a variety of countries, including China, Italy, and the United States. In April 2013, CGN was issued a 25-year license to mine DSO in the Montufar area, 40 km southeast of El Estor. After minimal processing,

the Montufar ores were trucked to the Port of Santo Tomas de Castilla on the Gulf of Honduras for export (Solway Investment Group, GmbH, undated).

Indonesia.—On January 12, 2014, the Government of Indonesia began enforcing a long-publicized ban on the export of key unprocessed metalliferous ores. The new regulations, originally enacted as Law No. 4 in 2009, effectively halted all sales of Indonesian nickeliferous DSO to overseas producers of ferronickel and NPI. The Government of Indonesia wanted foreign consumers to construct state-of-the-art ferroalloy and NPI facilities in the archipelago.

Some Chinese producers of NPI began blending their dwindling stocks of Indonesian ore with lower grade, limonitic lateritic ores imported from the Philippines. Other Chinese companies decided to build joint mining and smelting complexes on the island of Sulawesi. One example was the PT Indonesia Morowali Industrial Park under construction at Bahodopi in Central Sulawesi. The combined ferronickel and stainless-steel project was funded in part by Shanghai Decent Investment (Group) Co., Ltd., a China-based company founded in 2007 [Shanghai Decent Investment (Group) Co., Ltd., undated].

Antam was in the process of expanding its ferronickel production complex at the Port of Pomalaa, Southeast Sulawesi, and began construction of a greenfield ferronickel plant at East Halmahera, North Maluku. The $600 million expansion at Pomalaa was expected to be completed by the end of 2015. Construction of the $900 million ferronickel plant at East Halmahera was scheduled to be completed in 2018. The East Halmahera plant was to be constructed in two stages, with each stage capable of producing 13,500 to 15,000 t/yr of nickel [Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk, 2015b, p. 8].

In 2014, Antam produced 16,851 t of nickel in ferronickel, down 8% from 18,249 t in 2013. Sales of nickeliferous DSO, however, plummeted from 9.711 Mt (wet) to just 0.215 Mt (wet), as the result of the newly legislated embargo. Since January, all of Antam's DSO production was used as feed for its Pomalaa ferronickel plant. At yearend 2014, Antam had 130 Mt (wet) of proven and probable saprolite reserves, averaging 2.0% nickel, plus 380 Mt (wet) of limonitic resources averaging 1.4% nickel [Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk, 2015a, p. 134–135, 202–203; 2015b, p. 5, 20].

PT Vale Indonesia Tbk (Jakarta) had been in commercial production since 1978, but had never exported unprocessed ore. As a result, the company was largely unaffected by the export ban on DSO. PT Vale's product—nickel in matte—satisfied the minimum thresholds set out in the new Government regulations. In 2014, the company produced a record-high 78,726 t of nickel in matte at its Soroako complex, South Sulawesi. At the same time, PT Vale significantly cut operational costs by converting its ore dryers at Soroako from high-sulfur fuel oil to pulverized Indonesian coal. All of the matte was sold to the company's two principal shareholders—Vale Canada Ltd. (58.73% ownership) and Sumitomo Metal Mining Co., Ltd. (20.09%). A proposed conversion of the operation's reduction kilns from fuel oil to coal was expected to cut production costs even more dramatically than in 2014. At yearend 2014, PT Vale had 110 Mt of proven reserves grading 1.80% nickel and 17 Mt of probable reserves grading 1.75% nickel (PT Vale Indonesia Tbk, 2015, p. 10, 19–29, 92–102).

Madagascar.—In 2014, the Ambatovy Joint Venture produced 37,053 t of nickel metal briquets and 2,915 t of cobalt metal briquets and powder. The greenfield processing facility achieved commercial operation in January. The facility was expected to produce 54,000 t/yr of nickel—90% of nameplate capacity—after completing rampup of the lateritic mine and hydrometallurgical operation. Slurried ore from the mine near Moramanga was pumped through a 220-km-long pipeline to the processing plant and refinery near the Port of Toamasina. Sherritt International Corp. operated the vertically integrated complex, which was jointly owned by Sherritt (40%), Korea Resources Corp. (27.5%), Sumitomo Corp. (27.5%), and SNC-Lavalin Inc. (5%) (SNC-Lavalin Inc., 2014a; Sherritt International Corp., 2015, p. 2, 11, 13–14, 26).

New Caledonia.—At yearend 2014, Vale Nouvelle-Calédonie SAS (VNC) continued to ramp up production at its Grand Sud hydrometallurgical complex near Goro. The Grand Sud complex used a high pressure acid leach process to treat both limonitic and saprolitic ores. During the year, the mine delivered 2.13 Mt of lateritic ore averaging 1.44% nickel to the hydrometallurgical plant. The plant produced 10,660 t of nickel in nickel hydroxide cake averaging 16% nickel and 7,449 t of nickel in nickel oxide averaging 78% nickel. The mixed hydroxide precipitate, produced in the upstream part of the operation, was shipped to the Palmer Nickel and Cobalt Refinery in Queensland, Australia, for further processing. The nickel oxide was sent to Vale S.A.'s refineries at Dalian, China, and Kaohsiung, Taiwan, for conversion into utility nickel. At yearend 2014, VNC had 120 Mt of proven and probable reserves of dry ore grading 1.42% nickel. The $4.3 billion mining and processing complex was expected to have a production capacity of 57,000 t/yr of nickel in nickel oxide and nickel hydroxide cake when fully operational in 2016 (Direction de l'Industrie, des Mines et de l'Energie, 2015, p. 2; Vale S.A., 2015, p. 36, 39–41, 67).

Russia.—Norilsk Nickel was Russia's leading producer, accounting for about 99% of total primary nickel output for the year. About 83% of Norilsk Nickel's marketable nickel came from its Russian operations; the remainder came from company operations in Botswana and Finland. Norilsk Nickel's operations on the Kola and Taimyr Peninsulas had a combined output of 228,438 t of nickel metal. Norilsk Nickel's Russian subsidiaries exported almost all of their nickel production; only about 12,000 t, or 5%, was sold to Russian consumers and other buyers in the Commonwealth of Independent States (OJSC MMC Norilsk Nickel, 2015, p. 42–45, 52, 71, 212).

The southern Urals smelter on the outskirts of Orsk in Orenburgskaya Oblast' was idle throughout all of 2014. The owner, OAO Mechel (Moscow), suspended ferronickel production in December 2012 after global demand for the ferroalloy declined. The company's two laterite mines—Buruktal and Sakhara—also remained idle in 2014. On December 31, 2014, Mechel formally closed the smelting part of the complex after receiving approval from Government authorities in July 2013. Mechel's Chelyabinsk Metallurgical Plant and other steel operations consumed 2,600 t of nickel

during 2014 to produce stainless steel and other specialty steels. The nickel was supplied by JSC Ufaleynickel (Verkhny Ufaley) and ZAO Normetimpeks (a Moscow-based trading company) (OAO Mechel, 2015, p. 110, 137, F–40 to F–41).

Ufaleynickel was Russia's second-ranked nickel producer in 2014 and was capable of producing 16,000 t/yr of nickel in the form of nickel metal granules or nickel oxide powders. Ufaleynickel and its partners were in the process of upgrading both the Serov Mine in Sverdlovskaya Oblast' and the Verkhny Ufaley smelting operations in Chelyabinskaya Oblast'. The modernization program was guided by recommendations from the Chelyabinskaya Oblast' Ministry of Environmental and Radiation Safety. The smelter upgrade was intended to reduce consumption of coke; reduce emissions of sulfur dioxide, carbon monoxide, and nitrous oxides; reduce the amount of dust generated during the burning of the coke; and reclaim waste heat from the flue gas exhausts (International Nickel Study Group, 2013, p. C–31; JSC Ufaleynickel, 2014a, b).

Outlook

There is no economically viable substitute for nickel in austenitic stainless steel—at least for the immediate future. World stainless melt shop production has had a compound annual growth rate of about 6%, climbing from 1 Mt in 1950 to 41.7 Mt (gross weight) in 2014 (International Stainless Steel Forum, 2015b, p. 6–10, 27–30; Pinizzotto, 2015, p. 10–19, 27–29, 38).

The electric power industry is expected to remain an important consumer of austenitic stainless steel and various nickel-base superalloys—both for new construction and renovation. Global demand for electricity continues to increase and is accelerating as the population of the world increases. Electricity consumption in the United States alone is expected to increase by at least 29% between 2012 and 2040 (U.S. Energy Information Administration, 2014, p. MT–16).

The transportation manufacturing sector (aerospace, automobile, marine, and railway equipment manufacturers) is expected to significantly increase demand for nickel owing to increased demand for new vehicles that have more fuel-efficient engines. The Boeing Co. forecast an average growth rate of 4% to 5% per year for global passenger and cargo air traffic between 2014 and 2034 (Tinseth, 2014, p. 10–26; Boeing Co., The, 2015, p. 24).

The development of renewable energy sources is expected to accelerate research on cost-effective, more advanced batteries, especially for automobiles, telecommunication complexes, and remote power stations. Depending on material choices, this development could either increase or reduce nickel demand in battery applications (Tinseth, 2014, p. 10–26).

References Cited

American Iron and Steel Institute, 2015a, 2014 annual statistical report: Washington, DC, American Iron and Steel Institute, 121 p.

American Iron and Steel Institute, 2015b, Quarterly production of stainless and heat resisting steel (AIS 104)—Fourth quarter [2014]: Washington, DC, American Iron and Steel Institute, 2 p.

Anglo American plc, 2015a, Annual report 2014: London, United Kingdom, Anglo American plc, 216 p.

Anglo American plc, 2015b, Mine profile—Barro Alto: London, United Kingdom, Anglo American plc, October 6. (Accessed October 24, 2016, at http://www.angloamerican.com/media/our-stories/mine-profile-barro-alto.)

Barber, John, Eggleston, Ted, Parker, Harry, Gormely, Lynton, Frost, David, Allard, Simon, Hartley, Janine, Annavarapu, Srikant, White, Trey, Radue, Tom, Martin, Chris, Malgesini, Matthew, Sterrett, Robert, Pierce, Matthew, and Poeck, Joanna, 2014, Twin Metals Minnesota Project, Ely, Minnesota, USA, NI 43–101 technical report on pre-feasibility study: Mesa, AZ, AMEC E&C Services, Inc., August 20. (Accessed January 30, 2017, at http://www.twin-metals.com/wp-content/uploads/2012/09/TMM-Project-PFS-Technical-Report.pdf.)

Berry, Lucy, 2014, Carpenter Technology in Tanner opens $518 million premium metals plant several weeks ahead of schedule: Tanner, AL, Alabama Media Group, January 27. (Accessed October 12, 2016, at http://www.al.com/business/index.ssf/2014/01/carpenter_technology_in_tanner.html.)

BHP Billiton Ltd., 2014a, BHP Billiton operational review for the year ended 30 June 2014: BHP Billiton Ltd. news release, July 23, 28 p. (Accessed May 19, 2017, at http://www.bhpbilliton.com/-/media/bhp/documents/investors/reports/2014/140723_bhpbillitonoperationalreviewfortheyearended30june2014.pdf.)

BHP Billiton Ltd., 2014b, Form 20–F—2014: U.S. Securities and Exchange Commission, 393 p. plus financial statements.

BHP Billiton Ltd., 2015, BHP Billiton operational review for the half year ended 31 December 2014: BHP Billiton Ltd. news release, January 21, 26 p. (Accessed May 19, 2016, at http://www.bhpbilliton.com/~/media/bhp/documents/investors/news/2015/150121_bhpbillitonoperationalreviewforthehalfyearended31december2014.pdf.)

Boeing Co., The, 2015, Form 10–K—2014: U.S. Securities and Exchange Commission, 121 p. plus exhibits.

Carpenter Technology Corp., 2013, Carpenter selects Alabama for new superalloy powder facility: Wyomissing, PA, Carpenter Technology Corp., October 22. (Accessed October 7, 2016, at http://ir.cartech.com/phoenix.zhtml?c=64522&p=irol-newsArticle_Print&ID=1866717.)

Carpenter Technology Corp., 2014, The world's most advanced specialty metals manufacturing facility—Athens operations: Wyomissing, PA, Carpenter Technology Corp., 4 p. (Accessed February 3, 2017, at https://www.cartech.com/globalassets/literature-files/carpenterathensoperations.pdf.)

Departamento Nacional de Produção Mineral (Brazil), 2015, Sumario mineral—2014 [Portugese]: Brasilia, Brazil, Departamento Nacional de Produção Mineral, July, v. 35, 141 p. (Accessed May 15, 2017, via http://www.dnpm.gov.br/dnpm/sumarios/sumario-mineral-2014/view.)

Department of Mines and Petroleum (Western Australia), 2015, Western Australian mineral and petroleum statistics digest—2014: East Perth, Western Australia, Australia, Department of Mines and Petroleum (Western Australia), 47 p.

Direction de l'Industrie, des Mines et de l'Energie, 2015, Productions et exportations—Minieres & metallurgiques—De la Nouvelle-Caledonie (Décembre 2014): Noumea, New Caledonia, Direction de l'Industrie, des Mines et de l'Energie, January 21, 3 p. (Accessed March 23, 2017, at https://dimenc.gouv.nc/sites/default/files/statistiques_nc_2014_-_12.pdf.)

Duluth Metals Ltd., 2013, Investing in hard assets—Copper, nickel and PGMs in the United States: Toronto, Ontario, Canada, Duluth Metals Ltd. corporate presentation, March, 28 p. (Accessed March 8, 2013, at http://www.duluthmetals.com/i/pdf/DM_Presentation.pdf.)

ERAMET Group, 2015, Annual report 2014—The heart of our performance: Paris, France, ERAMET Group, 59 p.

Evans, Nick, and Lucas, Jarrod, 2015, Nickel industry braces for job cuts: The West Australian [Perth, Western Australia, Australia], October 2. (Accessed March 22, 2017, at https://thewest.com.au/news/wa/nickel-industry-braces-for-job-cuts-ng-ya-129949.)

Fattig, Paul, 2013, Mining firm interested in national forest nickel: Mail Tribune [Medford, OR], April 7. (Accessed April 29, 2015, at http://www.mailtribune.com/article/20130407/NEWS/304070332/-1/ARCHIVE.)

First Quantum Minerals Ltd., 2016, 2015 annual report: Vancouver, British Columbia, Canada, First Quantum Minerals Ltd., 94 p.

Ford Motor Co., 2014, Battery technologies, *in* Climate change and the environment, *of* Sustainability report 2012/13: Dearborn, MI, Ford Motor Co. (Accessed October 18, 2016, at http://corporate.ford.com/microsites/sustainability-report-2013-14/environment-products-electrification-battery.html.)

Glencore plc, 2015, Annual report 2014: Baar, Switzerland, Glencore plc, 204 p.

Gulf Chemical & Metallurgical Corp., 2013a, Refining refiners' spent catalysts: Freeport, TX, Gulf Chemical & Metallurgical Corp. press release, November 14. (Accessed July 10, 2015, at http://www.ERAMET-gulf.com/newsPublications_pressReleasesDetail.asp?NewsPublicationsID=18.)
Gulf Chemical & Metallurgical Corp., 2013b, Spent catalyst recycling: Freeport, TX, Gulf Chemical & Metallurgical Corp. (Accessed March 12, 2013, at http://www.ERAMET-gulf.com/SpentCatalystRecycling.asp.)
Gulf Chemical & Metallurgical Corp., 2014, Gulf 360°—Closing the loop: Freeport, TX, Gulf Chemical & Metallurgical Corp. diagram. (Accessed May 10, 2014, at http://www.ERAMET-gulf.com/about Gulf_360Process.asp.)
Horsehead Holding Corp., 2015, Form 10–K—2014: U.S. Securities and Exchange Commission, 70 p. plus exhibits.
Hybrid Shop, The, 2015, How is a Ford C-Max hybrid battery different from a regular battery?: The Hybrid Shop. (Accessed July 13, 2015, at http://www.thehybridshop.com/battery-conditioning/questions/how-is-a-ford-c-max-hybrid-battery-different-from-a-regular-battery/.)
International Nickel Study Group, 2013, World directory of nickel production facilities: Lisbon, Portugal, International Nickel Study Group, 5 sections (A–E).
International Nickel Study Group, 2015, World nickel statistics—Yearbook: Lisbon, Portugal, International Nickel Study Group Bulletin, v. 23, no. 11, November, 4 sections (A–D).
International Stainless Steel Forum, 2015a, Meltshop production statistics 2001 to 2014—Stainless and heat resisting steel meltshop production (ingot/slab equivalent)—Time series 2001 to 2014 in '000 metric tons: Brussels, Belgium, International Stainless Steel Forum. (Accessed July 6, 2015, at http://www.worldstainless.org/crude_steel_production/meltshop_production_2001_2014.)
International Stainless Steel Forum, 2015b, Stainless steel in figures—2015: Brussels, Belgium, International Stainless Steel Forum, 35 p. (Accessed November 30, 2016, at http://www.worldstainless.org/Files/issf/non-image-files/PDF/ISSF_Stainless_Steel_in_Figures_2015_English_Public.pdf.)
JSC Ufaleynickel, 2014a, Production and the environment—A priority: Verkhny Ufaley, Russia, JSC Ufaleynickel press release, September 4. (Accessed November 18, 2016, via http://www.ufaleynickel.ru/.)
JSC Ufaleynickel, 2014b, The meltshop of "Ufaleynickel" [has] installed equipment that has no analogs in Russia: Verkhny Ufaley, Russia, JSC Ufaleynickel press release, February 13. (Accessed November 18, 2016, via http://www.ufaleynickel.ru/.)
Klinger, Peter, 2013, Mirabela client claims breakdown kills deal: The West Australian [Perth, Western Australia, Australia], November 5. (Accessed October 31, 2016, at https://au.news.yahoo.com/thewest/wa/a/19687838/mirabela-client-claims-breakdown-kills-deal/#page1>.)
Leo, Anthony, [undated], Stationary fuel cell power systems with Direct FuelCell technology tackle growing distributed baseload power challenge: Danbury, CT, FuelCell Energy, Inc., 8 p. (Accessed July 7, 2015, at http://www.fuelcellenergy.com/assets/Fuel-Cell-Technology-White-Paper.pdf.)
London Metal Exchange Ltd., 2014, Nickel stocks: London, United Kingdom, London Metal Exchange Ltd., December 31.
Lundin Mining Corp., 2015, 2014 annual filings—December 31, 2014: Toronto, Ontario, Canada, Lundin Mining Corp., 200 p.
Martell, Allison, and Rocha, Euan, 2014, Work on Copper Cliff Deep to resume—Strong: The Sudbury [Ontario, Canada] Star, March 3. (Accessed March 22, 2017, at http://www.thesudburystar.com/2014/03/03/work-on-copper-cliff-deep-to-resume-strong.)
Mining-technology.com, [undated], Totten Mine, Sudbury: London, United Kingdom, Kable Intelligence Ltd. (Accessed November 2, 2016, at https://www.mining-technology.com/projects/totten-mine-sudbury/.)
Minnesota Minerals Coordinating Committee, 2014, 2013/2014 mineral development and exploration highlights: St. Paul, MN, Minnesota Department of Natural Resources, Division of Lands and Minerals, February. (Accessed August 13, 2014, at http://files.dnr.state.mn.us/lands_minerals/mpes_projects/mn_mineralhighlights_0214.pdf.)
Mirabela Nickel Ltd., 2015, Annual report—31 December 2014: Perth, Western Australia, Australia, Mirabela Nickel Ltd., 116 p.
Newby, Douglas, and Knudson, Jenny, 2015, Copper, nickel and precious metals in the U.S.: St. Paul, MN, PolyMet Mining Corp., presentation to investors, April, 18 p. (Accessed May 5, 2015, at http://www.polymetmining.com/wp-content/uploads/2013/02/PLM-Investor-Presentation-4.14.2015.pdf.)
Nickel Institute, 2016, The life of Ni: Toronto, Ontario, Canada, Nickel Institute, 18 p. (Accessed March 20, 2017, via https://www.nickelinstitute.org/en/MediaCentre/Publications/TheLifeofNi.aspx.)
OAO Mechel, 2015, Form 20–F—2014: U.S. Securities and Exchange Commission, 317 p. plus financial statements. (Accessed November 21, 2016, at http://www.sec.gov/Archives/edgar/data/1302362/000119312514201166/d654123d20f.htm.)
OJSC MMC Norilsk Nickel, 2015, Annual report—2014: Moscow, Russia, OJSC MMC Norilsk Nickel, 239 p. (Accessed February 7, 2017, at http://or2014.nornik.ru/en/apps/ar2014-nn-en.pdf.)
Oregon Water Resources Department, 2014, Final order to deny limited license application LL-1533: Salem, OR, Oregon Water Resources Department, September 30, 5 p.
Outokumpu Oyj, 2015, Annual report 2014: Espoo, Finland, Outokumpu Oyj, 120 p.
Pinizzotto, Salvatore, 2015, Update on nickel: Stainless and its Alloys Conference, 29th, Chicago, IL, October 27–28, 2015, presentation, 40 p.
PolyMet Mining Corp., 2015, Form 20–F—2015: U.S. Securities and Exchange Commission, 62 p. plus financial statements.
Poseidon Nickel Ltd., 2014, Annual report 2014: Perth, Western Australia, Australia, Poseidon Nickel Ltd., 102 p. (Accessed October 31, 2016, at http://poseidon-nickel.com.au/wp-content/uploads/2015/02/2014-Annual-Report.pdf).
Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk, 2015a, 2014 annual report—One spirit to overcome challenges: Jakarta, Indonesia, Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk., 602 p.
Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk, 2015b, Presentation to investors: Jakarta, Indonesia, Perusahaan Perseroan (Persero) PT Aneka Tambang Tbk, September 1, 32 p.
PT Vale Indonesia Tbk, 2015, 2014 annual report—Growing together through operational excellence: Jakarta, Indonesia, PT Vale Indonesia Tbk, 422 p.
Queensland Nickel Pty Ltd., [undated], Operational overview, *in* About QN: Yabulu, Queensland, Australia, Queensland Nickel Pty Ltd. (Accessed June 29, 2015, at https://www.qni.com.au/about-qn/operational-overview/.)
Raglan Mine, 2015, Sivumut Project: Laval, Quebec, Canada, Glencore Canada Corp., fact sheet. (Accessed July 17, 2015, at http://www.mineraglan.ca/EN/OurBusiness/Documents/Sivumut_%20Fact%20Sheet_21_ANG.pdf.)
Reuters, 2013, Brazil's Votorantim to halt Mirabela Nickel contract, close plant: Thomson Reuters Corp., September 27. (Accessed October 31, 2016, at http://www.reuters.com/article/brazil-nickel-idUSL2N0HN11F20130927.)
Roberts, Terry, 2014, Vale, Province celebrate first production at new nickel plant in Long Harbour: CBC News, November 19. (Accessed August 18, 2016, at http://www.cbc.ca/news/Canada/newfoundland-labrador/vale-province-celebrate-first-production-at-new-nickel-plant-in-Long-Harbour-1.2840691.)
Shanghai Decent Investment (Group) Co., Ltd., [undated], Indonesia Morowali Industrial Park, *in* We in Indonesia: Shanghai, China, Shanghai Decent Investment (Group) Co., Ltd. (Accessed November 15, 2016, at http://www.decent-china.com/EN/index.php/Channel/Index/id/175.html.)
Shepherd, Josh, 2015, Stainless steel's Kentucky home: The Lane Report, July 9. (Accessed October 5, 2016, at http://www.lanereport.com/51152/2015/07/stainless-steels-kentucky-home/.)
Sherritt International Corp., 2015, 2014 annual report: Toronto, Ontario, Canada, Sherritt International Corp., 142 p.
Sieminski, Adam, 2014, Outlook for U.S. shale oil and gas: Annual meeting of the Allied Social Science Associations, Philadelphia, PA, January 4, presentation, 20 p. (Accessed July 10, 2015, at http://www.eia.gov/pressroom/presentations/sieminski_01042014.pdf.)
SNC-Lavalin Inc., 2014a, Ambatovy nickel project—Madagascar: Montreal, Quebec, Canada, SNC-Lavalin Inc., October 24. (Accessed November 16, 2016, at http://www.snclavalin.com/en/ambatovy-nickel-project-madagascar.)
SNC-Lavalin Inc., 2014b, Preliminary information—The Raglan Mine property beyond 2020 (Phase II and III)—Continuation of mining operations east of Katinniq: Levis, Quebec, Canada, SNC-Lavalin Inc., Project 615202-000-4EER-0017, November. (Accessed March 22, 2017, at http://www.keqc-cqek.ca/wordpress/wp-content/uploads/2015/02/3215-14-03_Raglan_phases_II_III_preliminary_info_WA.pdf.)
Solway Investment Group, GmbH, [undated], Fenix nickel project (Guatemala), *in* Our business: Solway Investment Group, GmbH. (Accessed November 10, 2016, at http://www.solwaygroup.com/index.php/our-business/fenix-project-guatemala.)
Spinetto, J.P., 2013, Anglo American sees Barro Alto nickel output cut until 2016: Bloomberg News, September 24. (Accessed February 4, 2015, at http://www.bloomberg.com/news/articles/2013-09-23/anglo-american-sees-barro-alto-nickel-output-cut-until-mid-2016.)

Stillwater Mining Co., 2015, Form 10–K—2014: U.S. Securities and Exchange Commission, 112 p. plus certifications.
Tesla Motors Inc., [undated]a, About Tesla: Palo Alto, CA, Tesla Motors Inc. (Accessed October 18, 2016, at https://www.tesla.com/about.)
Tesla Motors Inc., [undated]b, Tesla Gigafactory: Palo Alto, CA, Tesla Motors Inc. (Accessed October 18, 2016, at https://www.tesla.com/gigafactory.)
Tinseth, Randy, 2014, Current market outlook—2014: Chicago, IL, The Boeing Co., presentation, 28 p. (Accessed August 21, 2014, at http://www.boeing.com/assets/pdf/commercial/cmo/pdf/CMO_2014_Presentation.pdf.)
U.S. Energy Information Administration, 2014, Annual energy outlook 2014, with projections to 2040: Washington, DC, U.S. Energy Information Administration, DOE/EIA–0383, April, 268 p.
U.S. Mint, [undated]a, Circulating coin production figures: Washington, DC, U.S. Mint. (Accessed January 26, 2017, via https://competition.usmint.gov/circulating-coins-production-figures/.)
U.S. Mint, [undated]b, Coin specifications, *in* Coin and medal programs, *of* Learn: Washington, DC, U.S. Mint. (Accessed January 26, 2017, at https://www.usmint.gov/about_the_mint/index583f.html?action=coin_specifications.)
Vale Canada Ltd., 2016, Long Harbour nickel melt rounds: Toronto, Ontario, Canada, Vale Canada Ltd., May. (Accessed November 1, 2016, at http://www.vale.com/EN/business/mining/nickel/NickelProducts/Long%20Harbour%20Melt%20Rounds.pdf.)
Vale S.A., 2013, Onça Puma resumes production in Para: Rio de Janeiro, Brazil, Vale S.A. press release, November 14. (Accessed February 5, 2015, at http://www.vale.com/EN/aboutvale/news/Pages/onca-puma-retoma-producao-no-para.aspx.)
Vale S.A., 2015, Form 20–F—2014: U.S. Securities and Exchange Commission, 164 p. plus financial statements.
Welch, Mike, Mariuzza, Kristen, Johnson, Matt, and Conibear, Paul, 2014, Eagle Mine site visit—November 3–4, 2014: Toronto, Ontario, Canada, Lundin Mining Corp. presentation, 51 p. (Accessed April 30, 2015, at http://www.lundinmining.com/i/pdf/2014-11-03_EMSVP.pdf.)

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 of contained nickel unless otherwise specified)

		2010	2011	2012	2013	2014
United States:						
Production, concentrate		--	--	--	--	4,300
Secondary recovery from purchased scrap:						
From ferrous scrap		74,100 r	78,900 r	82,300 r	81,100 r	81,800
From nonferrous scrap		8,640	11,400	12,100	12,100 r	12,400
Shipments of purchased scrap[2]		139,000	134,000 r	132,000 r	128,000 r	112,000
Exports:						
Ores and concentrates[3]		4,710	1,890	760	1,020	3,320
Primary		12,600	12,400	9,100	10,600	10,400
Secondary		80,300	64,800	59,800	61,200	56,400
Imports for consumption:						
Ores and concentrates[3]		32	1	(4)	3	92
Primary		129,000	138,000	133,000	126,000	156,000
Secondary		23,800	21,300	22,300	26,300	38,900
Consumption:						
Reported:						
Primary		100,000	110,000	114,000	114,000	115,000
Secondary, purchased scrap		82,700 r	90,200 r	94,400 r	93,100 r	94,200
Total		183,000 r	200,000 r	208,000 r	207,000 r	209,000
Apparent, primary		114,000	124,000 r	125,000	110,000	151,000
Apparent primary plus reported secondary		197,000 r	215,000 r	220,000 r	203,000 r	245,000
Stocks, yearend:						
Producers and traders		6,240	6,650 r	6,380	10,000 r	9,030 p
Consumer, primary		10,700	11,400	10,100	12,000	11,800
Consumer, secondary		6,280 r	6,750 r	6,630 r	6,720 r	12,100
Total		23,200 r	24,800 r	23,100 r	28,700 r	32,900
Price, cash, London Metal Exchange:						
Average annual	dollars per metric ton	21,804	22,890	17,533	15,018	16,865
Average annual	dollars per pound	9.890	10.383	7.953	6.812	7.650
Price, Type 304 stainless steel scrap, gross weight:[5]						
Average annual	dollars per metric ton	2,200	2,276	1,859	1,574	1,714
Average annual	dollars per long ton	2,235	2,312	1,889	1,599	1,742
World, mine production		1,690,000 r	2,180,000 r	2,420,000 r	2,790,000 r	2,260,000

pPreliminary. rRevised. -- Zero.

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

[2]Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.

[3]Nickel ores and concentrates (Harmonized Tariff Schedule of the United States code 2604.00.0040). Source: U.S. Census Bureau.

[4]Less than ½ unit.

[5]Derived from the monthly averages of the consumer buying price in Pittsburgh, PA, as published in American Metal Market. The price represents Type 304 solids and clips containing 18% to 20% chromium and 8% to 12% nickel.

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

(Metric tons of contained nickel)

	2013[r]	2014
Kind of scrap:		
Aluminum-base[2]	2,090	2,010
Copper-base	1,240	1,360
Ferrous-base[3]	81,100	81,800
Nickel-base	8,730	9,000
Total	93,100	94,200
Form of recovery:		
Aluminum-base alloys	2,090	2,010
Copper-base alloys	2,310	2,410
Ferrous alloys	83,600	84,900
Nickel-base alloys	5,140	4,810
Total	93,100	94,200

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Primarily borings and turnings of wrought alloys, such as 2218, 2618, 4032, and 8280, or special casting alloys, such as 203.0.
[3]Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

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

(Metric tons of contained nickel)

Form	2013	2014
Primary:		
Metal	95,500 [r]	96,900
Ferronickel	15,100	15,600
Oxide and oxide sinter[2]	208 [r]	232
Chemicals[3]	791	1,070
Other	1,920 [r]	1,500
Total	114,000	115,000
Secondary, scrap[4]	93,100 [r]	94,200
Grand total	207,000 [r]	209,000

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Under investigation.
[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 of contained nickel)

Use	2014								Grand total in 2013
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total	
Cast irons[2]	59	--	--	--	3	62	211	273	258
Chemicals and chemical uses	1,500	--	W	624	5	2,130	--	2,130	2,020
Electric, magnet, expansion alloys	208	W	22	--	1	231	--	231	250
Electroplating, sales to platers	8,280	--	--	W	(3)	8,280	--	8,280	8,080 r
Nickel-copper and copper-nickel alloys	W	--	(3)	--	52	52	2,250	2,300	2,100 r
Other nickel and nickel alloys	14,700	71	5	171	40	15,000	W	15,000	16,400
Steel:									
Stainless and heat resistant	36,500	13,300	83	--	102	50,000	82,800	133,000	129,000 r
Alloys, excludes stainless	3,010	32	--	--	97	3,140	192	3,330	5,500 r
Superalloys	25,100	124	--	1	962	26,200	W	26,200	26,700 r
Other[4]	7,330	2,100	122	442	235	10,200	8,710	18,900	16,800
Total	96,700	15,600	232	1,240	1,500	115,000	94,200	209,000	207,000 r

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Under investigation.
[3]Less than ½ unit.
[4]Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by symbol W.

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

(Metric tons of contained nickel)

Form	2013	2014
Primary:		
Metal	10,700	10,700
Ferronickel	1,010	894
Oxide and oxide sinter	25 r	32
Chemicals[2]	98	20
Other	157 r	162
Total	12,000	11,800
Secondary, scrap	6,720 r	12,100
Grand total	18,700 r	23,900

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Under investigation.

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

Class	2013 Quantity (metric tons of contained nickel)	2013 Value (thousands)	2014 Quantity (metric tons of contained nickel)	2014 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	1,540	$24,900	1,990	$35,600
Ferronickel	479	8,040	111	3,140
Powder and flakes	1,590	58,800	1,710	59,700
Metallurgical-grade oxide[2]	2,210	17,400	1,970	22,000
Chemicals:				
Catalysts[3]	3,820	269,000	3,420	316,000
Salts[4]	910	18,900	1,210	29,400
Total	10,600	397,000	10,400	466,000
Secondary:				
Stainless steel scrap	48,300	743,000	41,100	674,000
Waste and scrap[5]	12,900	110,000	15,200	125,000
Total	61,200	853,000	56,400	799,000
Grand total	71,800	1,250,000	66,800	1,260,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	368	11,600	223	9,390
Sheets, strip, foil	304	11,700	247	9,870
Tubes and pipes	56	1,770	210	4,640
Total	728	25,000	680	23,900
Alloyed, gross weight:				
Unwrought alloyed ingot	5,100	113,000	5,350	128,000
Bars, rods, profiles, wire	19,800	704,000	20,600	676,000
Sheets, strip, foil	11,600	384,000	12,700	372,000
Tubes and pipes	2,100	131,000	2,360	155,000
Other alloyed articles	3,810	425,000	4,210	480,000
Total	42,400	1,760,000	45,200	1,810,000

[1]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 shipment is assumed to 50% nickel; stainless steel scrap, 7.5%.

Source: U.S. Census Bureau.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS, BY COUNTRY[1, 2]

(Metric tons of contained nickel)

	2014									
Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2013	Wrought nickel in 2014[4]
Argentina	2	35	--	6	27	14	70	154	53	(5)
Australia	--	4	--	(5)	1,180	3	37	1,220	864	1
Belgium	--	10	--	130	--	108	40	288	531	7
Brazil	136	44	1	(5)	4	2	293	480	769	10
Canada	49	234	89	1,160	9,560	2,290	1,130	14,500	12,800	31
China	15	284	(5)	138	(5)	9,150	815	10,400	8,820	41
Colombia	31	13	--	--	--	2	109	155	57	18
France	--	6	--	(5)	9	2	53	70	48	16
Germany	1	286	1	19	123	226	128	784	574	59
Hong Kong	--	12	--	6	--	918	7	943	476	6
India	--	70	--	3	81	2,700	158	3,010	4,500	9
Italy	--	5	--	(5)	--	11	56	72	406	21
Japan	--	87	--	18	1,950	2,040	48	4,140	4,060	4
Korea, Republic of	(5)	75	--	(5)	38	2,830	118	3,060	7,500	15
Malaysia	(5)	1	--	3	7	38	62	111	210	5
Mexico	1,560	160	--	14	7	313	217	2,270	1,720	46
Netherlands	170	16	--	--	64	63	132	445	1,770	(5)
Pakistan	--	1	--	--	--	5,680	6	5,690	5,860	--
Singapore	1	138	3	3	2	12	25	184	222	24
South Africa	--	9	--	3	--	(5)	7	19	104	--
Spain	--	1	--	--	--	34	1	36	419	5
Sweden	--	13	3	--	443	236	1	696	487	1
Taiwan	16	41	14	--	45	13,500	62	13,700	16,400	44
Thailand	--	44	(5)	--	11	507	56	618	598	2
United Kingdom	5	44	--	420	1,420	32	161	2,080	914	49
Venezuela	2	1	--	(5)	--	3	64	70	74	61
Vietnam	--	1	--	--	--	213	--	214	356	8
Other	1	76	--	48	287	196	773	1,380	1,180 r	194
Total	1,990	1,710	111	1,970	15,200	41,100	4,630	66,800	71,800	677

rRevised. -- Zero.

[1]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, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.

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

[4]Not included in "2014, Total."

[5]Less than ½ unit.

Source: U.S. Census Bureau.

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

Class	2013 Quantity (metric tons of contained nickel)	2013 Value (thousands)	2014 Quantity (metric tons of contained nickel)	2014 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	104,000	$1,630,000	126,000	$2,100,000
Ferronickel	13,700	212,000	20,500	313,000
Powder and flakes	5,690	120,000	5,730	125,000
Metallurgical-grade oxide[2]	687	14,500	851	17,300
Chemicals:				
Catalysts[3]	1,590	92,800	1,770	100,000
Salts[4]	1,010	20,000	1,030	25,700
Total	126,000	2,090,000	156,000	2,690,000
Secondary:				
Stainless steel scrap	17,000	211,000	24,700	426,000
Waste and scrap[5]	9,350	149,000	14,300	216,000
Total	26,300	359,000	38,900	642,000
Grand total	153,000	2,450,000	195,000	3,330,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	274	8,070	288	8,310
Sheets, strip, foil	464	13,300	356	10,200
Tubes and pipes	120	4,330	82	2,470
Total	859	25,700	726	20,900
Alloyed, gross weight:				
Unwrought alloyed ingot	10,900	221,000	13,300	221,000
Bars, rods, profiles, wire	10,300	273,000	12,100	315,000
Sheets, strip, foil	2,930	68,700	4,310	95,000
Tubes and pipes	2,000	165,000	1,640	99,300
Other alloyed articles	1,810	165,000	1,760	179,000
Total	27,900	892,000	33,100	910,000

[1]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 shipment is assumed to 50% nickel; stainless steel scrap, 7.5%.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY[1, 2]

(Metric tons of contained nickel)

	2014									
Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2013	Wrought nickel in 2014[4]
Australia	14,900	417	--	627	149	3	--	16,100	11,800	--
Belgium	80	129	--	--	12	7	266	494	298	--
Brazil	5,760	--	2,640	--	287	884	--	9,560	4,640	--
Canada	53,600	3,920	26	68	3,570	10,900	61	72,100	69,900	5
China	260	71	646	--	572	10	13	1,570	1,070	17
Colombia	--	--	7,780	--	11	172	--	7,960	3,240	--
Dominican Republic	--	--	--	--	34	--	--	34	2,440	--
Finland	10,500	74	--	--	--	--	62	10,600	7,970	--
France	428	12	--	1	1,010	1	516	1,970	2,080	188
Germany	--	68	8	--	1,460	--	317	1,850	1,010	289
Guatemala	--	--	715	--	(5)	29	--	744	5	--
India	--	--	--	14	43	1	318	376	197	53
Indonesia	15	--	--	141	15	--	107	278	260	--
Israel	--	(5)	--	--	124	29	--	153	38	2
Italy	--	1	--	--	201	1	6	209	58	1
Japan	2,670	88	(5)	(5)	1,100	39	210	4,110	1,220	25
Madagascar	4,610	--	--	--	--	--	--	4,610	3,140	--
Mexico	--	16	--	1	1,040	9,670	15	10,700	10,100	--
Netherlands[6]	--	11	--	--	14	2,400	408	2,830	339	1
New Caledonia	--	--	6,090	--	--	--	--	6,090	4,160	--
Norway	18,600	--	--	--	9	--	--	18,600	10,800	--
Russia	12,900	128	--	--	59	--	(5)	13,000	9,400	--
Singapore	74	--	--	--	366	9	(5)	449	274	(5)
South Africa	1,250	254	--	--	--	--	3	1,510	737	--
Spain	--	(5)	--	--	85	4	5	94	35	--
Taiwan	--	1	--	--	229	89	9	328	183	(5)
Ukraine	--	--	938	--	--	--	--	938	2,530	--
United Kingdom	487	526	303	--	3,100	94	156	4,670	3,600	55
Venezuela	--	--	1,360	--	--	--	--	1,360	--	--
Other	59	14	--	--	786	372	322	1,550	1,100 r	91
Total	126,000	5,730	20,500	852	14,300	24,700	2,790	195,000	153,000	727

rRevised. -- Zero.

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

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

[3]Primarily oxide, rondelles, and sinter.

[4]Not included in "2014, Total."

[5]Less than ½ unit.

[6]The different nickel products (cathode, powder, and so forth) are apparently materials that have transited through bonded warehouses in the Netherlands, including warehouses overseen by the London Metal Exchange.

Source: U.S. Census Bureau.

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

(Metric tons of contained nickel)

Country and products[3]	2010	2011	2012	2013	2014
Albania, laterite ore[e]	3,000	3,000	1,000 [r]	2,100 [r]	4,900 [p]
Australia, ores and concentrate[4]	170,100 [r]	215,000 [r]	244,000 [r]	234,000 [r]	245,000
Botswana, ore milled	24,931	15,675	17,948	22,848	14,958 [p]
Brazil, ore	108,983	131,673	139,230	104,829 [r]	167,063 [p]
Burma, ore[e, 5]	--	800	5,000	9,000 [r]	21,000
Canada, concentrate	160,063	219,025	211,701	227,743 [r]	234,951 [p]
China, ore[e]	79,600 [r]	94,500 [r]	103,860 [r, 6]	107,160 [r, 6]	98,400 [p]
Colombia, laterite ore, mined[e]	76,200	76,000	84,000	84,700	NA
Cuba, recoverable laterite:[e]					
Limonitic	32,500	38,100	35,700	34,500	26,300
Serpentinitic	37,200	34,400	32,500	31,500	24,100
Total	69,700	72,500	68,200	66,000	50,400
Dominican Republic, laterite ore	--	21,693	25,590	15,825	--
Finland, concentrate[7]	12,100 [r]	18,800 [r]	19,590 [r]	19,440 [r]	18,730
Greece, laterite ore[8]	16,345	21,710	21,980	19,100 [e]	21,405
Guatemala, laterite ore[9]	--	--	2,400	10,200 [e]	38,400
Indonesia, laterite ore	300,800	564,400	648,400	834,200	177,100
Kazakhstan, laterite ore[e]	500	500	450	-- [r]	--
Kosovo, laterite ore	9,081	7,728	4,436	7,606	6,724
Macedonia:[e]					
Laterite ore	1,800	3,600	1,680	NA	NA
Ferronickel produced[10]	14,413 [6]	17,292 [6]	19,427 [6]	20,001 [6]	20,000
Total	16,200	20,900	21,100	20,001 [6]	20,000
Madagascar, mixed sulfide	(11)	(11)	8,365	29,248	40,267
Morocco, nickel sulfate	317	217	288	175	220
New Caledonia, ore	131,309	128,732	131,693	164,406	178,080
Norway, concentrate	351	339	351	335	375 [p]
Papua New Guinea, laterite ore (mixed hydroxide)	--	--	5,283 [12]	11,369 [12]	20,987 [12]
Philippines:					
Laterite ore	150,000 [r]	202,000 [r]	322,000 [r]	464,000 [r]	523,000
Concentrate	19,312	22,794	23,890	26,020	50,647
Total	169,312 [r]	224,794 [r]	345,890 [r]	490,020 [r]	573,647
Russia, marketable mine production:					
Laterite ore[13]	41,184	41,777	26,620 [r]	10,400 [r, e]	11,200 [p]
Sulfide concentrate[14]	228,093	225,616	217,085	220,242 [r]	218,589
Total	269,277	267,393	243,705 [r]	231,000 [r, e]	229,789
South Africa, concentrate	39,960	43,321	45,945	51,208	54,956
Spain, concentrate[15]	6,296 [r]	--	2,398 [r]	7,574 [r]	8,631
Turkey, laterite ore[e]	1,900	4,300	3,500 [r]	1,200 [r]	1,900
United States, concentrate	--	--	--	-- [r, 16]	4,300 [p]
Venezuela, laterite ore	11,400	19,500	6,060	3,500 [r, e]	3,800 [e]
Vietnam, concentrate	--	--	335	1,166 [r]	6,854
Zambia, concentrate	2,482	2,724	--	--	--
Zimbabwe, concentrate	6,200 [e]	7,992	7,899	12,962 [r]	16,633
Grand total	1,690,000 [r]	2,180,000 [r]	2,420,000 [r]	2,790,000 [r]	2,260,000
Of which:					
Concentrate[17]	475,000 [r]	541,000 [r]	529,000 [r]	567,000 [r]	615,000
Ore and ore milled[18]	345,000 [r]	371,000 [r]	398,000 [r]	408,000 [r]	480,000
Laterite ore	682,000 [r]	1,040,000 [r]	1,220,000 [r]	1,530,000 [r]	860,000
Ferronickel produced[10]	14,000 [r]	17,000 [r]	19,000 [r]	20,000	20,000
Mixed sulfide	(11)	(11)	8,370	29,000	40,000
Nickel sulfate	317	217	288	175	220
Unspecified and (or) undifferentiated[19]	170,000 [r]	215,000 [r]	244,000 [r]	234,000 [r]	245,000

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

[1]Includes data available through June 1, 2016. Grand total 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 was not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this was noted.

TABLE 10—Continued
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of contained nickel)

[3]In addition to the countries listed, North Korea may have an active nickel mine, but information was inadequate to make reliable estimates of output.

[4]Australian Bureau of Agricultural and Resource Economics (ABARE) data for mines in Western Australia and Tasmania.

[5]Burma's new Tagaung Tang Mine is a joint project of the Government of Burma, China's Taiyuan Iron & Steel, and the China Nonferrous Metal Mining Group (CNMC). The nickel content of the ore mined and the nickel content of ferronickel produced were reported by the Government.

[6]Reported figure.

[7]The gross weight of concentrates processed in Finland from domestic ores was, in metric tons, as follows: 2010—43,151; 2011—87,974; 2012—99,089; 2013—137,911; and 2014—126,801.

[8]Source: Greek Mining Enterprise Association. The gross weight laterite ore railed from Greek mines was, in metric tons, as follows: 2010—1,942,000; 2011—2,236,000; 2012—2,257,000; 2013—2,221,000; and 2014—2,317,000.

[9]Cunico Resources Group N.V. mined high-grade saprolitic ores for export to eastern Europe. Solway Investment Group GmbH was also active in Guatemala at the Fenix Mine and ferronickel plant west of El Estor.

[10]Cunico Resources Group extracted nickel ore from its open pit Rzanovo Mine and transported the ore by conveyor to its FeNi Industries pyrometallurgical facility in Kavadarci. At the Kavadarci plant, the Rzanovo ore was blended with higher grade imported ores from Albania, Indonesia, New Caledonia, and Turkey to optimize production.

[11]Build-up ore stockpile.

[12]The Ramu joint venture piped slurried ore from the Kurumbukari Mine to a treatment plant at Basamuk, where nickel-cobalt hydroxide was produced.

[13]Nickel content of ore mined in the Ural Mountains region.

[14]Nickel content of concentrate produced on the Kola and Taimyr Peninsulas.

[15]In December 2010, Rio Narcea Recursos, S.A. suspended production at its Aguablanca open pit mine after heavy rainfall caused a major slope failure on the main access ramp. Mining resumed in August 2011, but milling operations did not restart until the third quarter of 2012.

[16]In 2013, Lundin Mining Co. recovered 4,093 metric tons of nickel in nickel-copper ore from the Eagle Mine in Michigan. The concentrator at the Humboldt mill did not begin processing the ore until the third quarter of 2014.

[17]Includes "Russia, sulfide concentrate."

[18]Does not include "Australia, ores and concentrate."

[19]Includes "Australia, ores and concentrate."

TABLE 11
NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY[1, 2, 3]

(Metric tons of contained nickel)

Country	2010	2011	2012	2013	2014
Matte:					
Australia[4]	59,186	56,200	66,294 r	68,999	61,545 p
Botswana	25,127	28,800 e	17,948	22,848	14,958
Brazil[5]	14,308	13,703	14,345	11,641	12,000
Canada[6]	70,127	73,724	80,765	86,007	79,347 p
China[7]	1	--	--	--	--
Finland	10,381	16,088	12,915	8,662	8,363
Indonesia[8]	75,989	66,900	70,717	75,802	78,726
New Caledonia	13,917	13,780	13,417	13,279	8,241
Philippines	20,500	22,794	23,890	26,021	50,647
Russia[9]	85	65	1	--	--
South Africa	--	--	--	5,800	--
Zimbabwe[10]	3,105	3,519	3,787	7,500	--
Total	293,000	296,000	304,000	327,000	314,000
Other:					
Cuba:[e, 11]					
Sulfide precipitate	34,197 [12]	34,816 [12]	34,325 [12]	34,300	34,300
Ammoniacal liquor precipitate and unspecified	2,400	2,400	2,300	2,300	2,300
Total	36,600	37,200	36,600	36,600	36,600
New Caledonia, nickel hydroxide cake	222	7,374 [13]	3,378	7,557	12,464
Papua New Guinea, mixed hydroxide product	--	--	5,283	11,369	20,987
Total, other	36,800	44,600	45,300	55,500	70,100
Grand total	330,000	340,000	349,000	382,000	384,000

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

[1]Includes data available through December 14, 2017. Data represent nickel content of matte and other intermediate materials produced.

[2]Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[3]Source: International Nickel Study Group (INSG) World Nickel Statistics.

[4]Figures exclude toll-refined material. Total matte production on a contained nickel basis, in metric tons, was as follows: 2010—59,200; 2011—56,200; 2012—63,300; 2013—70,000; and 2014—72,000.

[5]Represents the output of the Fortaleza smelter. All of the Fortaleza matte was shipped to Finland for further processing.

[6]Nickel content of reported exports. Matte from the smelter at Falconbridge typically assayed 55% nickel.

[7]Chinese exports were estimated to have a nickel content of 63%. Total matte production on a contained nickel basis, in metric tons, was estimated as follows: 2010—139,000; 2011—166,000; 2012—153,000; 2013—160,000; and 2014—168,000.

[8]Represents the nickel output of the Soroako smelter. The Soroako matte was shipped to Japan for further processing and contained on average 78% nickel.

[9]Primarily exports to China. Sources: International Nickel Study Group (INSG) and United Nations Statistics Division. The average nickel content of the exported matte was estimated to be 25%.

[10]Zimplats matte shipped to the Impala Refinery at Springs, South Africa.

[11]Corrected to remove byproduct cobalt.

[12]Reported figure.

[13]Derived from both limonitic laterite and saprolitic laterite ores after 2010.

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

(Metric tons of contained nickel)

Country and products[3]	2010	2011	2012	2013	2014
Australia:					
Metal	92,208	97,655	115,796	133,019	130,799 p
Unspecified[4]	9,390	12,558	12,963	8,500	7,901 p
Total	101,598	110,213	128,759	141,519	139,000 p
Austria, ferronickel and ferronickel molybdenum	600	700	800	1,000	1,000 p
Brazil:[5]					
Ferronickel	8,465	16,750	31,342	34,501	37,237 p
Metal	19,111	20,521	21,437	19,823	21,000 p
Total	27,576	37,271	52,779	54,324	58,237 p
Burma, ferronickel[6]	--	--	--	4,200 r, p	15,300 p
Canada, unspecified[7]	105,413	142,445	139,800	154,181 r	131,948
China:[e, 8]					
Ferronickel and high nickel pig iron[9]	158,000	248,400	353,200	480,000	470,000
Metal	159,000	175,000	197,000	245,000	251,000
Chemicals and unspecified	8,500	8,900	9,000	9,000	21,000
Total	326,000	432,000	559,000	734,000	742,000
Colombia, ferronickel	49,443	37,817	51,595	49,320	41,200 p
Cuba, oxide sinter and oxides[10]	27,098	19,186	25,702	15,279 r	15,000 e
Dominican Republic, ferronickel	--	13,528 r	15,186	9,400	--
Finland:[11]					
Metal, electrolytic, including cathode and briquettes	41,317	43,840	40,131 r	38,098 r	36,080
Chemicals and unspecified, including powder, salts, solutions, and other	7,842 r	5,983 r	6,144 r	6,400 e	6,670
Total	49,159 r	49,823 r	46,275 r	44,500 r, e	42,750
France:					
Metal	10,799	11,697	11,311 r	10,300 r, e	7,141
Chemicals	2,080	2,039	1,927	1,821 r	1,263
Total	12,879	13,736	13,238 r	12,100 r, e	8,404
Greece, ferronickel	13,956	18,527	18,632	16,890	18,481
Guatemala, ferronickel for export	--	--	--	--	5,000
India, ferronickel magnesium[12]	96	107	114	200	200 e
Indonesia, ferronickel	18,688	19,690	18,373	18,249	16,851
Japan:					
Ferronickel	64,350	62,773	73,248	80,554 r	70,070
Metal	40,228	41,290	41,944 r	46,405 r	56,129
Oxide sinter	59,011	50,437	51,999	48,873 r	45,907 p
Chemicals	2,497	2,383	2,362	2,191	5,673
Total	166,086	156,883	169,553 r	178,023 r	177,779
Korea, Republic of:					
Ferronickel	20,512	19,011	20,858	25,376	22,799 p
Metal	(13)	(13)	(13)	(13)	(13)
Total	20,512	19,011	20,858	25,376	22,799
Kosovo, ferronickel	9,081	7,728	6,944	7,562 r	8,500 e
Macedonia, ferronickel	14,413	17,292	19,247	20,001	18,054 p
Madagascar, metal	--	--	5,695	25,148	37,053
Morocco, chemicals, including nickel sulfate	(14)	(14)	(14)	(14)	(14)
New Caledonia:					
Ferronickel	39,802	40,015	43,030	40,459	54,863
Nickel oxide sinter	--	--	2,353	7,911	7,366 p
Total	39,802	40,015	45,383	48,370	62,229
Norway, metal	92,185	92,427	91,687	91,017 r	90,500 p
Russia:					
Ferronickel					
High-nickel	16,799	16,899	9,782	--	--
Other[e, 15]	5,330	5,360	3,110	--	--
Total, ferronickel[e]	22,100	22,300	12,900	--	--
Metal	262,400	264,900	255,000	241,800 r	231,000 p
Chemicals[e]	2,900	2,900	2,900	2,600	2,700
Total, Russia[e]	287,000	290,000	271,000	244,000	234,000

See footnotes at end of table.

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

(Metric tons of contained nickel)

Country and products[3]	2010	2011	2012	2013	2014
South Africa:					
Ferronickel, high-nickel	614	575	658	650 e	--
Metal	34,700	35,900	32,900	45,458 r, p	49,856 p
Chemicals[16]	5,353	5,564	5,093	5,100 e	5,100 e
Total	40,667	42,039	38,651	51,200 e	55,000 e
Taiwan, metal[e, 13]	400	400	400	400	400
Ukraine, ferronickel[17]	15,467	14,640 r	20,628 r	21,184 r	18,615 p
United Kingdom, metal[18]	31,650	37,400	34,300 r	42,400 r, p	39,100 p
Venezuela, ferronickel	11,700	13,300	8,100	--	4,000 e
Zimbabwe, metal, toll refined from imported nickel feed[19]	4,039	3,715	1,754	2,845	2,400
Grand total	1,470,000	1,630,000	1,800,000	1,980,000 r	1,950,000
Of which:					
Ferronickel, including ferronickel magnesium, ferronickel molybdenum, and high nickel pig iron	447,000	553,000 r	695,000	805,000 r	792,000
Metal	788,000	825,000	844,000 r	917,000 r	915,000
Oxide sinter	86,100	69,600	77,700 r	64,200 r	60,900
Chemicals, including nickel sulfate	12,800	12,900	12,300	11,700 r	14,700
Unspecified	131,000	170,000 r	168,000	178,000 r	168,000

eEstimated. pPreliminary. rRevised. -- Zero.

[1]Grand totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through December 19, 2017.

[3]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 produced nickel-containing matte and other intermediate nickel products, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries that produced matte for export are listed in table 11.

[4]Class II products with a nickel content of less than 99%. Data includes oxides and oxide sinter and excludes intermediate nickel-cobalt sulfide matte, regulus, and speiss for further refining.

[5]Source: Departamento Nacional de Produção Mineral [DNPM]-Relatório Anual de Lavra [RAL]/Diretoria de Planejamento e Desenvolvimento da Mineração [DIPLAM]-RAL, Ministério do Desenvolvimento, Indústria e Comércio Exterior [MDIC]/Secretaria de Comércio Exterior [SECEX] (DNPM Sumário Mineral 2010–2014). Production year 2009 is under investigation. Brazil also produced nickel carbonate (an intermediate product for metal production), in metric tons: 2009—16,766; 2010—18,580 (revised); 2011—19,381; 2012—19,611 (revised); and 2013—19,958. Companhia Brasileira de Metalurgia e Mineração (CBMM) produced nickel niobium for sale to the superalloys industry.

[6]Joint project of the Government of Burma, China's Taiyuan Iron & Steel, and the China Nonferrous Metal Mining Group (CNMC). The nickel content of ferronickel produced was reported by the Government.

[7]Numbers have been adjusted to take into account data received from individual company sources as well as trade statistics.

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

[9]Reported figure.

[10]Cuba also produced nickel sulfide and ammoniacal liquor precipitate, but because they were used as feed material elsewhere, they were not included to avoid double counting.

[11]Reported by Eramet for Sandouville. Includes a small amount of cobalt that was not recovered separately, but excludes secondary production from spent rechargeable batteries.

[12]India's fiscal year ending March 31 of the year stated.

[13]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.

[14]Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.

[15]Includes ferronickel chromium and nickel-resist cast iron.

[16]Includes nickel sulfate plus exported metal in concentrate.

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

[18]Includes nickel content of chemicals.

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