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NICKEL [ADVANCE RELEASE]

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NICKEL

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Global consumption of nickel continued to increase in 2013, despite sluggish demand in Japan, the Republic of Korea, and much of the European Union (EU). The overall growth was driven by increased use of stainless steel and superalloys, especially in China and India. This growth was spurred on by (1) the economic recovery in the United States, and (2) the long-term global decline in poverty (Economist, The, 2013; International Nickel Study Group, 2014, p. A–1, A–6). World production of stainless and heat-resisting steel reached a record high of 38.5 million metric tons (Mt) in 2013, but the growth was uneven geographically, with downturns taking place in Germany, Italy, the Republic of Korea, and Russia (ERAMET Group, 2015a, p. 18; 2015b, p. 3, 19; International Stainless Steel Forum, 2015). Global stainless steel production for 2013 was 7% greater than the revised figure of 35.9 Mt for 2012. World mine production of nickel reached an alltime high of 2.66 Mt of contained nickel in 2013, surpassing the previous high of 2.41 Mt in 2012 (table 10). The London Metal Exchange Ltd. (LME) average monthly cash price for nickel metal peaked in February 2013 at $17,729 per metric ton, but then began an extended decline as new mining projects were commissioned. The LME cash price ended the year at $13,911 per metric ton and averaged $15,018 per metric ton for 2013. Daily stocks of nickel metal continued to increase in LME-sanctioned warehouses throughout 2013 and ended the year at 261,468 metric tons (t)—an alltime high at that moment in time.

Austenitic (nickel-bearing) stainless steel has accounted for 60% of global primary nickel consumption for more than a decade (Nickel Institute, undated). China was the leading producer of austenitic stainless steel in 2013, accounting for about 53% of world output, as well as the leading consumer of primary nickel. In 2013, China produced more austenitic stainless steel than the United States, India, Japan, the Republic of Korea, Taiwan, and all of the countries in the EU combined. On a global basis, nonferrous alloys accounted for about 12% of primary nickel use; electroplating and other surface finishing, 11%; alloy steels other than stainless, 10%; and batteries, catalysts, and specialty chemicals, 7% (ERAMET Group, 2015b, p. 17–24; Mistry, 2012, p. 7; Nickel Institute, undated, appendix 3).

Reported nickel consumption (primary plus secondary) in the United States in 2013 decreased slightly compared with that of 2012. U.S. apparent consumption of primary nickel was 110,000 t, or about 6% of world consumption, based on the 1.78 Mt reported by the International Nickel Study Group (INSG). Stainless steel production accounted for only 41% of U.S. primary consumption, a reflection of the large number of specialty metal industries and a readily available supply of stainless steel scrap in the United States (table 4). U.S. industry reported melting 88,800 t of nickel contained in scrap, a decrease of 4% from 92,400 t (revised) in 2012 (table 3) (International Nickel Study Group, 2015).

Legislation and Government Programs

Recovery Act Projects.—Many of the advanced projects involving power generation have the potential to increase demand for nickel metal and (or) nickel-bearing alloys. Nickel-base superalloys are commonly used to fabricate critical components of steam or gas turbines. Superalloy piping is used to bring hot, corrosive geothermal brines to the surface where the heat can be transferred to a more conventional storage facility constructed from less expensive alloys. Some of the projects supported by the U.S. Department of Energy had applications for both transportation and power generation. One example was the development of improved stationary and portable fuel-cell power systems (U.S. Energy Information Administration, 2014a, p. IF 41–45, A1, A16, A17; 2014b, p. 5).

Stationary fuel-cell power systems generate electricity 24 hours per day, unlike solar photovoltaic systems and wind turbines. Fuel cells internally reform hydrogen from natural gas, biofuels, or ethanol, emitting dramatically reduced amounts of carbon dioxide (CO_2) in the process, compared with the emissions from the boiler stack of a conventional coal-fired power plant. 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® developed by FuelCell Energy, Inc. (Danbury, CT) uses porous nickel catalysts for both the anode and cathode. The cathode receives oxygen from the air, while the anode receives hydrogen produced in a reforming reaction between the hydrocarbon fuel and water (Leo, undated).

U.S. Coinage.—The U.S. Mint increased coin production in 2013 for the fourth 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 2013 contained 2,630 t of nickel in the form of either cupronickel or manganese brass alloy. In 2013, the Mint produced a total of 1,223 million Jefferson nickels (25% nickel by weight) and 2,112 million Roosevelt dimes (8.33% nickel), up from 1,024 million nickels and 1,676 million dimes in 2012 (U.S. Mint, undated b). The Jefferson nickels contained a total of 1,529 t of nickel and the Roosevelt dimes contained 399 t of nickel. Minting of quarters increased by 156% from 2012 to 2013. The U.S. Mint produced 1,455 million commemorative quarters in 2013, up from 568 million in 2012, but still far below production levels directly prior to the 2008–09 recession. The different designs on the reverse (tail side) of the quarters continued to promote the Nation's parks and historical sites. Five different designs were released in 2013. Each coin weighed 5.67 grams and contained 8.33% nickel, for a total of 687 t of nickel (U.S. Mint, undated a, b).

Production

The United States had no nickel mine production in 2013. However, a chalcopyrite-pentlandite mine was under construction in Michigan, and several other sulfide deposits were in varying stages of development in Minnesota. Limited quantities of byproduct nickel were recovered at some copper and precious metal refineries. The refinery recovery data are included with the scrap statistics in tables 2 through 5.

No ferronickel was produced in the United States in 2013 from ores. Almost all U.S. ferronickel exports were either re-exports or material upgraded for special purposes. The steel industry accounted for more than 85% of the ferronickel consumed in 2013, of which more than 99% was used in stainless, heat-resistant, or specialty alloy steels.

Michigan.—In February 2013, the management of the Rio Tinto Group decided to refocus the company's capital on long-life, large-tonnage, low-cost mining operations. This mining model was incongruous with the company's $469 million Eagle project underway on the Upper Peninsula of Michigan. Instructions were subsequently given to slow down construction at both the nickel-copper Eagle Mine, southwest of Big Bay in Michigamme Township, and at the renovated Humboldt mill near Champion. Despite the slowdown, more than 80% of the construction work at the Eagle Mine was completed by June 2013 (Pepin, 2013b).

In July, Rio Tinto sold 100% of the underground mine and unfinished mill to Lundin Mining Corp. (Toronto, Ontario, Canada) for $318 million in cash. Lundin planned to spend an additional $400 million to bring the mine and mill into production by late 2014. Production would be ramped up during the first quarter of 2015 and reach full capacity by mid-2015. The mine was expected to produce an average of 17,300 metric tons per year (t/yr) of nickel and 13,200 t/yr of copper in concentrates during the first 6 years of its life (Lundin Mining Corp., undated). The State of Michigan and local authorities later approved Lundin's plans to truck ore from the underground mine to Humboldt, where separate concentrates of copper and nickel sulfides would be produced. The two sulfide concentrates would then be shipped by railroad from Humboldt to Canada or shipped overseas for smelting. At yearend 2013, the Eagle Mine had 5.33 Mt of proven and probable reserves grading 3.1% nickel, 2.5% copper, and 0.1% cobalt (Owen and Meyer, 2013; Pepin, 2013a, b; Rio Tinto plc, 2013; Lundin Mining Corp., 2014a, p. 51; 2014b; 2015, p. 17, 20, 67, 104–106).

Minnesota.—PolyMet Mining Corp. (Vancouver, British Columbia, Canada) was waiting for approval from the State of Minnesota to begin mining the NorthMet deposit 9.7 kilometers (km) [6 miles (mi)] south of the town of Babbitt in St. Louis County. PolyMet was in the late stages of a comprehensive environmental review that began in 2004. In November 2013, an interagency team composed of the Minnesota Department of Natural Resources, the U.S. Army Corps of Engineers, and the U.S. Forest Service (USFS) released a Supplemental Draft Environmental Impact Statement (SDEIS) that included a proposal to exchange land held by PolyMet in the Superior National Forest for equivalent USFS land that encompassed the mine site. If approved, the land exchange would allow cost-effective surface mining. The U.S. Environmental Protection Agency did not author the SDEIS, but has been serving as an independent reviewer. The general public had until March 2014 to comment on the SDEIS and its conclusions (Minnesota Department of Natural Resources, U.S. Army Corps of Engineers, and U.S. Forest Service, 2013; PolyMet Mining Corp., 2014, p. 13–22).

NorthMet, a copper, nickel, and platinum-group-element (PGE) deposit at the western end of the Duluth Complex, was estimated to have 249 Mt of proven and probable reserves averaging 0.28% copper and 0.082% nickel. The deposit was more than 4 km (2.5 mi) in length and extended to a depth of more than 790 meters (m) (2,600 feet) at some locations. Ore from a proposed open pit would be shipped to the reconditioned Erie mill near Hoyt Lakes 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 at the Erie site (Desautels and Zurowski, 2012, p. 1–1 to 1–10; Newby and Knudson, 2015).

Duluth Metals Ltd. (Toronto), Teck American Inc. (Spokane, WA), and Twin Metals Minnesota LLC (St. Paul, MN, a joint venture of Antofagasta plc and Duluth Metals) 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). The Twin Metals Minnesota (TMM) project is located 14 km (9 mi) southeast of Ely. An AMEC E&C Services Inc. NI 43–101 Technical Report confirmed 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 contain 1.8 Mt of copper and 560,000 t of nickel, based on a copper cutoff grade of 0.3%. Combined indicated resources at the Maturi, Maturi Southwest, and Birch Lake deposits include an additional 5.2 Mt of copper and 1.7 Mt of nickel. The TMM project was in the early stages of development in 2013, with a prefeasibility study scheduled for completion in June 2014 (Dundas and others, 2013, p. 5–9; Barber and others, 2014; Duluth Metals Ltd., 2014, p. 15–20 and 24–35).

Oregon.—At yearend, the USFS continued to evaluate a permit application submitted by Red Flat Nickel Corp. (Portland, OR) to explore for nickel in the Rogue River-Siskiyou National Forest. The proposed drilling program would initially focus on an area about 13 km (8 mi) east-southeast of Gold Beach in Curry County (LithoLogic Resources, LLC and Alyssum Ventures Ltd., 2012, p. 1–12; Fattig, 2013; Lanier, 2013).

Byproduct Smelter and Refinery Production.—In 2013, Stillwater Mining Co. (Billings, MT) shipped 612 t of nickel in crystalline sulfate, up from 508 t in 2012. 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 the company'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, petroleum refining, and chemical processing catalysts. The nickel and copper sulfides

which occur naturally in the concentrates act as a metallurgical collector in the smelter furnace and facilitate extraction of the PGEs from the recycled materials (Stillwater Mining Co., 2015, p. 7–8, 20–21, 52, 60–61).

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., 2014, 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. 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 crude, but marketable, nickel-cobalt-molybdenum alloy in a direct-current electric arc furnace (EAF). 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 decreased to 110,000 t in 2013, from 125,000 t (revised) in 2012. The estimated value of apparent primary nickel consumption was $1.66 billion, a decrease from $2.20 billion (revised) in 2012 owing in part to a 14% decrease in the LME cash price. Apparent primary consumption plus reported secondary consumption in 2013 totaled 199,000 t, a decrease of 19,000 t from that in 2012 (table 1).

Stainless Steel and Low-Alloy Steels.—In 2013, stainless steel producers accounted for 41% of reported primary nickel consumption in the United States (table 4) and more than 60% of primary consumption in the world. Alloy steels—other than stainless—accounted for an additional 3% of U.S. nickel use. Production of raw stainless steel and heat-resisting steel in the United States totaled 2.03 Mt in 2013, up by 3% from 1.98 Mt in 2012. Nickel-bearing grades accounted for 1.42 Mt, or 70% of total stainless steel production (American Iron and Steel Institute, 2014a, p. 72–73; 2014b). North American Stainless, the Kentucky subsidiary of Acerinox, S.A., was the leading U.S. producer of flat-rolled stainless steel in 2013 and had more than 1,350 employees.

Outokumpu USA LLC continued to ramp up production at its integrated stainless steel mill at Calvert, AL. The stainless steel meltshop at Calvert was designed to produce up to 1 million metric tons per year (Mt/yr) of stainless steel slabs, but was still in the final stages of commissioning at the beginning of 2014. The meltshop had a 160-t-capacity EAF, 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. Rampup of the entire Calvert complex was hampered, in part, by a complicated agreement with the European Commission that linked rampup to the cutting of the company's financial ties to ThyssenKrupp AG (Essen, Germany) and the divestment of Outokumpu's stainless steel mill in Terni, Italy (Outokumpu Oyj, 2014, p. 2, 4–6, 16–19; 2015, p. 3, 17–19).

Superalloys and Related Nickel-Base Alloys.—Of the primary nickel consumed in the United States in 2013, approximately 23% was used to make high-performance superalloys and related nickel-base alloys, primarily for the aerospace, electric power, and petrochemical industries. Sales of superalloys to manufacturers of jet aircraft engines and other sectors of the aerospace industry increased in 2013, as Airbus Group, N.V. (Leiden, Netherlands) and the Boeing Co. (Chicago, IL) ramped up production of both high-value twin-aisle aircraft and legacy single-aisle aircraft, such as the A320 and 737 (Aerospace Industries Association, 2014, p. 2–4, 6, 10–14; Boeing Co., The, 2014, p. 24–29, 123–124; Airbus Group, N.V., 2015, p. 22; 40–42).

At yearend 2013, Allegheny Technology Industries, Inc. [ATI (Pittsburgh, PA)] was in the process of commissioning its hot-rolling and processing facility for advanced specialty metals at the company's existing flat-rolled operations in Brackenridge, PA. Commissioning was expected to be completed by the fourth quarter of 2014. The new facility, budgeted at $1.16 billion, would produce high-quality hot-rolled coils from a variety of metals and alloys, including nickel-base alloys, titanium metal, titanium alloys, zirconium alloys, and select grades of specialty stainless steels. The new facility was designed to produce thinner and wider coils than was possible in the past (Allegheny Technologies Inc., 2014, p. 14, F–15).

General Electric Aviation [an operating unit of General Electric Co. (GE)] and Rolls-Royce plc (London, United Kingdom) both have long-term sourcing agreements with ATI to ensure an adequate supply of the nickel-base ATI 718Plus® superalloy. The advanced superalloy was manufactured into a variety of jet engine components and is now beginning to be used in industrial gas turbines. ATI also has begun producing Rene 65, a futuristic, near-powder, nickel-base superalloy designed for the aerospace market (Greenfield, 2012; Allegheny Technologies Inc., 2014, p. 4, 9, 16, F–4).

Use of Nickel Alloys in the Power Generation Sector.—In 2013, generation of electricity in the United States by nonhydropower renewables (geothermal, solar, wind, and so forth) surpassed that of conventional hydropower for the first time. Solar and geothermal plants together accounted for only 6% of U.S. renewable energy consumption. Wind was the second-leading renewable source after hydropower (U.S. Energy Information Administration, 2014a, table D–4, p. D–10 to D–11; 2015, table A16, p. A–31 to A–32).

The three most common methods of generating electricity require turbines, reciprocating engines, or photovoltaic panels. In 2013, the United States generated 39.0% of its electricity by burning coal. Another 27.8% was obtained by burning natural gas. Nuclear powerplants and conventional hydroelectric powerplants supplied 19.5% and 6.7%, respectively. These figures show that more than 90% of U.S. power was generated using some type of turbine, whether it be steam, gas, or water (U.S. Energy Information Administration, 2015, p. 24, A–1, A–4).

The critical components of industrial steam turbines must withstand temperatures approaching 600 °C and have a service life of more than 25 years. To meet these criteria, more than 200 t of sophisticated alloys of nickel and chromium may be needed to make key parts of each industrial turbine. To reduce material costs, the turbine is composed of different alloys—depending upon the temperature encountered at various locations in the turbine. The more expensive nickel alloys are only employed in the hottest, more critical areas of the turbine. Researchers are currently designing a turbine that will operate at 700 °C in futuristic coal-fired powerplants, allowing the plant to sharply cut coal consumption while reducing CO_2 emissions. Nickel-bearing superalloys similar to those used in jet engines could make the 700 °C operating temperature attainable. Alcoa Power and Propulsion (a business unit of Alcoa Inc.), ATI, Certified Alloy Products Inc. (a Long Beach, CA, subsidiary of Doncasters Group Ltd.), and Precision Castparts Corp. (Portland, OR) were all examples of U.S. companies that produced high-performance superalloys for both aerospace and industrial gas turbines (Müller, 2008, p. 32–35; Völker and Riebisch, 2014).

An energy revolution began to take hold in the United States at the beginning of the 21st century. One component has been the development of "fracking" processes to economically extract crude oil and natural gas from oil shale formations in North Dakota, Pennsylvania, and Texas. The global economics of oil and gas extraction has begun to change owing to the increasing number of oil shale fields being brought into production. The increase in oil and gas extraction, in turn, has spurred construction of natural-gas-fired powerplants in Canada and Mexico as well as in the United States. Many of these new gas-fired plants are energy-efficient combined cycle plants (CCPs)—plants that often have both a gas turbine and a steam turbine—each fabricated in part from superalloys and austenitic stainless steel. The CCP steam turbine is often designed to use waste heat from the gas turbines (Economist, The, 2014, p. 17, 81–82; Ray, 2015; U.S. Energy Information Administration, 2015, p. 15–17, 24–27).

Another use of nickel was to retrofit older coal-fired powerplants. The retrofitting was driven by concerns about global climate change and the proposed adoption of more stringent environmental regulatory rules. The inlets of the turbines would be fabricated from high-performance superalloys and would receive steam at temperatures as high as 760 °C (1,400 °F) (Moverare and others, 2011, p. G2–2; Russell, Ray, 2015, p. 20–23; Schwant and others, 2013).

Nickel-Based Batteries and Hybrid Electric Vehicles.—U.S. demand for nickel in rechargeable batteries continued to increase. In 2013, many of the (non-plug-in) hybrid electric vehicles on U.S. highways still used NiMH batteries despite recent advances in lithium battery technology. In the past, Ford Motor Co., Honda Motor Co., Ltd., and Toyota Motor Corp. have all relied on NiMH batteries because of their proven durability, stability, and safety. Most of the NiMH batteries installed in post-2007 hybrid models were still functioning after 175,000 km (110,000 mi) of driving. 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 design. For example, the 2014 C–MAX hybrid manufactured by Ford was equipped with a 1.4-kilowatthour lithium-ion battery. The cathode of the battery was fabricated from a proprietary mixture of cobalt, manganese, and nickel oxides (Ford Motor Co., 2015; Hybrid Shop, The, 2015; Vandeputte, 2012, p. 10–16).

GE has been marketing its Durathon® family of batteries since 2011—sodium-metal-halide batteries that contain nickel chloride as a key cell constituent. The advanced battery, originally designed for backup power at data centers, reportedly could store three times more energy than an equivalent conventional lead-acid battery. One of the first uses was to provide backup power for cellular phone towers, especially ones in developing countries with unreliable electrical grids. Other potential applications were storing energy at wind farms or powering hybrid locomotives, mining trucks, and ship engines. The batteries were being manufactured at a renovated plant in Schenectady, NY (Coy, 2012; General Electric Co., 2013).

Stocks

Stocks of nickel metal in LME-sanctioned warehouses were gradually built up during the second half of 2012 and kept increasing throughout all of 2013. By January 31, 2013, LME stocks had risen to 150,900 t, dwarfing inventories held from 2000 through 2007. LME stocks continued to increase even more during the spring as new nickel plant production came onstream in Brazil, Burma, China, Madagascar, and New Caledonia. In July, LME stocks exceeded 200,000 t for the first time in history, even though nickel consumption was rising in China and the economies of key countries such as Brazil and the United States were recovering from an economic downturn. LME stocks kept rising during the winter and ended 2013 at 261,468 t. Data collected by the INSG (2014, p. A1–A2) indicated that, at yearend 2013, world nickel producers (excluding those in Austria, China, Macedonia, Kosovo, and the Ural region of Russia) held an additional 87,600 t of primary nickel stocks. About 73%, or 63,800 t, of the producer stocks was class I material (refined products with a nickel content of 99% or greater), which included, in order of decreasing quantity, electrolytic cathode, briquets, pellets, powder, and rondelles. The remaining 27%

was class II material, which included ferronickel, oxide sinter, and East Asian utility nickel. All stocks in LME-sanctioned warehouses were class I material. At yearend, U.S. consumer stocks of primary nickel totaled 12,000 t, 19% greater than the 10,100 t (revised) held at yearend 2012 (tables 1, 5).

Prices

Nickel prices continued to decline in 2013 despite growth in a large part of the global economy. Production from newly commissioned smelters and refineries more than offset increased consumption of the metal. Increased production of nickel pig iron (NPI) in China weakened demand for imported ferronickel by the world's leading producer of stainless steel. The January 2013 average LME cash price for 99.8%-pure metal was $17,460 per metric ton ($7.920 per pound). A high of $17,729 per metric ton ($8.042 per pound) was reached in February, followed by 5 months of declining prices. The average monthly price reached a low of $13,702 per ton ($6.215 per pound) in July and stagnated near that level for the rest of 2013. The monthly average price for December was $13,911 per metric ton ($6.310 per pound), about 20% less than that of January. The average annual LME price was $15,018 per metric ton ($6.812 per pound)—14% less than the 2012 average.

World Review

The world's leading producer of nickel ore was MMC Norilsk Nickel (Russia), followed by Vale S.A. (a "national origin" company with headquarters in Brazil and Canada) and the BHP Billiton Group (with headquarters in Australia and United Kingdom). PT Aneka Tambang Tbk. (Antam) (Indonesia) was in fourth place, producing large tonnages of direct-shipping ore (DSO) for the Chinese NPI industry.

According to the INSG, world use of primary nickel was 1.78 Mt in 2013—an alltime high for the fourth consecutive year—and was 7% greater than the previous high of 1.66 Mt in 2012 (International Nickel Study Group, 2015, p. A–1, A–7). Global mine production increased by 10% to a record-high 2.66 Mt. Mine production in Canada increased by 5% to a record-high 223,295 t of contained nickel.

In May 2013, Glencore International plc completed its acquisition of Xstrata plc, forming Glencore Xstrata plc, with headquarters in Baar, Switzerland. The new global company had a market value of about $66 billion at the time of the merger and was a major producer and marketer of over 90 commodities. Before the merger, Glencore's metals and minerals business segment focused on the mining of iron ore and the downstream processing of bauxite and chromite. Glencore Xstrata, however, was also heavily involved in the extraction and refining of many base and precious metals. Nickel assets included mining, smelting, and (or) refining operations in Australia, Canada, the Dominican Republic, New Caledonia, and Norway. In 2013, Glencore Xstrata's nickel operations generated $2.48 billion of the company's total industrial revenues for metals and minerals of $31.2 billion (Glencore Xstrata plc, 2014a, p. 8–9, 52, 196–199; Scott, 2013).

Global demand continued to be buoyed by the increase in apparent consumption in China, which rose to 871,000 t in 2013 from 472,000 t in 2009. China's stainless steel industry continued to expand and used a record-high 704,000 t of primary nickel in 2013, a 16% increase from the 607,000 t consumed in 2012. China's stainless steel industry was the leading consumer of primary nickel in the world. The steel industry of the EU consumed 200,000 t of primary nickel in 2013, whereas Japan's steel industry was in third place with 73,000 t (ERAMET Group, 2015a, p. 17–24). According to the International Stainless Steel Forum (2015), global stainless steel production increased to a record-high 38.5 Mt in 2013 from 35.9 Mt (revised) in 2012 and 33.6 Mt in 2011.

Australia.—Australia was the fourth-ranked nickel-producing country in the world in terms of refinery output, and also fourth in mine output. Eight companies in Western Australia reported producing salable nickel in 2013. Three of the eight trucked sulfide ore to BHP Billiton's concentrator at Kambalda for further processing (Western Australia Department of Mines and Petroleum, 2014, p. 38–39).

Laterite Operations.—The Palmer Nickel and Cobalt Refinery (formerly named Yabulu) processed laterite ores purchased from independent mining operations in Indonesia, New Caledonia, and the Philippines. The refinery was located 25 km northwest of the Port of Townsville and was operated by Queensland Nickel Pty. Ltd. In 2013, Palmer produced about 34,100 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 (ERAMET Group, 2015b, p. 23; Queensland Nickel Pty. Ltd., 2012).

First Quantum Minerals Ltd. processed 3.12 Mt of beneficiated lateritic ore averaging 1.6% nickel at its Ravensthorpe complex in Western Australia. This was the second full year of commercial operation for First Quantum's Australian subsidiary. About 76% of the nickel was recovered, down slightly from 77% in 2012. First Quantum spent $150 million modifying the front end of Ravensthorpe after purchasing the complex from BHP Billiton in February 2010. In 2013, Ravensthorpe produced 38,103 t of nickel contained in a mixed nickel-cobalt-hydroxide intermediate (First Quantum Minerals Ltd., 2014, p. 10, 32).

Glencore Xstrata's Murrin Murrin complex near Leonora, 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 35,900 t of nickel metal, an increase of 7% from that produced in 2012 and a record high for the complex. An additional 4,100 t of nickel was in marketable concentrates. At yearend 2013, Murrin Murrin had 201 Mt of proven and probable reserves, averaging 0.95% nickel and 0.067% cobalt (Glencore Xstrata plc, 2014a, p. 57; 2014b, p. 37).

Sulfide Operations.—The Avebury Mine [MMG Ltd. (Southbank, Victoria)] in Tasmania remained on care-and-maintenance status throughout 2013. MMG's major shareholder was China Minmetals Nonferrous Metals Co. Ltd. (Beijing, China).

In 2013, Nickel West, a subsidiary of BHP Billiton, produced 66,100 t of metal briquettes and powder at its Kwinana refinery in Western Australia from matte produced at its Kalgoorlie

smelter. Kwinana also produced several intermediate products, including ammonium sulfate, cobalt-nickel sulfide, and copper sulfide. The Kalgoorlie smelter produced an additional 35,000 t of nickel in finished matte (68% nickel) or concentrate for export. About one-third of the concentrate feed for the smelter came from the Mount Keith Mine in the Northern Goldfields region. The other two-thirds came from Nickel West's Perseverance-Cliffs mining operations near Leinster and third party mines at Kambalda. On October 31, BHP Billiton suspended production at its Perseverance underground mine after a significant seismic event interrupted operations. Closure of the mine also led to a cutback in smelter production at Kalgoorlie (BHP Billiton, 2014, p. 67–68, 160–165, 171).

Western Areas NL mined 317,000 t of sulfide ore grading 4.6% nickel and containing 14,713 t of recoverable nickel at its Flying Fox underground mine at Forrestania in the fiscal year ending June 30, 2014. The company also extracted 282,000 t of ore grading 5.0% nickel and containing 13,973 t of recoverable nickel from its Spotted Quoll underground operations, 6 km south of Flying Fox. The ores were fed to the company's Cosmic Boy mill, which produced 25,700 t of nickel in concentrate (Western Areas NL, 2014, p. 5, 10–13).

In April, Norilsk Nickel Australia Pty. Ltd. suspended mining at Lake Johnston and put the entire operation on care-and-maintenance status (OJSC MMC Norilsk Nickel, 2014, p. 31).

Three other companies mined nickel sulfide ores in Western Australia during 2013: Independence Group NL (Long Mine), Mincor Resources NL (Mariners, McMahon, Mittel, and Otter Juan Mines), and Panoramic Resources Ltd. (Savannah and Lanfranchi Tramways Mines) [Department of Mines and Petroleum (Western Australia), 2014, p. 38–39].

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.

Anglo American's new $1.9 billion Barro Alto mining and smelting complex in Goias State produced 25,100 t of nickel in ferronickel in 2013, 16% more than the 21,600-t output of 2012. 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 electric furnaces in order to correct inherent design problems discovered during the partial rampup (Moore, 2012; Spinetto, 2013; Anglo American plc, 2014a, p. 72–75; 2014b).

The mine at Barro Alto continued to supply ore to the Codemin ferronickel plant in Niquelandia for blending. In 2013, Codemin produced 9,300 t of nickel in ferronickel, 3% less than the 9,600 t of 2012. At yearend 2013, the Barro Alto Mine had 45.3 Mt of proven and probable reserves of saprolite averaging 1.55% nickel (702,000 t of nickel). Niquelandia had 5.6 Mt of slightly lower-grade ore averaging 1.30% nickel. Anglo American was evaluating two other laterite deposits in Brazil—Jacaré and Moro Sem Boné (Anglo American plc, 2014b, p. 76–81).

Vale S.A. (Brazil) also experienced furnace problems at its greenfield Onça Puma ferronickel smelting complex in Ourilandia do Norte, Para State. Vale was forced to suspend operations in June 2012 after both of its furnaces were damaged during rampup. Vale rebuilt one of the two damaged furnaces at an estimated cost of $188 million and resumed production with a single line in November 2013. The calcine transfer system was redesigned, new refractories were introduced, and several plant safety improvements were made during the renovation. The nominal capacity of the single-line operation was 25,000 t/yr of nickel in ferronickel. Onça Puma produced a total of 1,900 t of nickel in ferronickel during the last 2 months of 2013. At yearend 2013, the Onça Puma Mine had 95.3 Mt of proven and probable reserves averaging 1.61% nickel (Reuters, 2012; Vale S.A., 2013, p. 1; 2014b, p. 37–44, 65; Jannotti, 2014).

Votorantim Metais Níquel S.A. was the leading producer of electrolytic nickel in Latin America and operated a nickel-cobalt refinery in Sao Miguel Paulista, Sao Paulo State, capable of producing 23,000 t/yr of 99.9%-pure electrolytic nickel and an estimated 3,000 t/yr of electrolytic cobalt. The Sao Miguel Paulista refinery processed intermediate nickel carbonate from the company's operation in Niquelandia. The refinery produced 19,823 t of electrolytic nickel in 2013, down from 21,437 t in 2012. The sulfide smelter of Votorantim Metais at Fortaleza de Minas, Minas Gerais State, produced 11,641 t of nickel in matte in 2013, primarily for export to Finland, down from 14,345 t in 2012. The matte typically assayed 50% to 55% nickel, 7% to 12% copper, and 0.14% to 1% cobalt [International Nickel Study Group, 2014, p. B–5, B–6; Departamento Nacional de Produção Mineral (Brazil), 2014, p. 96–97].

Mirabela Nickel Ltd. (Perth, Western Australia, Australia) produced sulfide concentrate at its Santa Rita Mine near Ipiau, Bahia State. In 2013, Mirabela produced 15,626 t of nickel in concentrate, a decrease from 19,253 t in 2012. Mirabela trucked 9,431 t (about 60%) of the nickel 1,350 km to Votorantim's Fortaleza smelter in Minas Gerais and exported 2,776 t (18%) of the nickel to Norilsk's Harjavalta smelter in Finland. Another 1,395 t (9%) was sold in-country to an undisclosed international trading house. At yearend 2013, the Santa Rita open pit reportedly had 140 Mt of proven and probable ore reserves grading 0.52% nickel (Mirabela Nickel Ltd., 2014, p. 8–11).

Burma.—The Tagaung Taung (Dagongshan) ferronickel smelter was commissioned in the first quarter of 2013. The nickel laterite mine and adjacent smelter are in the Sagaing/Mandalay Region, less than 200 km from the Chinese border. Seven Volvo A30E articulated haulers (heavy-duty dump trucks) were being used to transport the ore from the mine to the crusher. A special pipe conveyor of Chinese design carried the pulverized ore from the crusher to the smelter. The rotary kiln electric furnace (RKEF) facility was designed to produce 25,000 t/yr of nickel in ferronickel pellets. The 72-megavoltampere electric furnace was successfully tapped on March 5, as part of a trial run (Metallurgical Corporation of China, Ltd., 2013).

Canada.—Four Provinces had active nickel mines in 2013—Manitoba, Newfoundland and Labrador, Ontario, and Quebec. In addition, companies were evaluating a variety of

nickel deposits in all but two of the remaining nine Provinces or Territories.

Manitoba.—Vale Canada's operations at Thompson processed 24,500 t of refined nickel in 2013 from ores extracted from the Birchtree and Thompson Mines. The Thompson Mine processed 1.18 Mt of ore grading 2.07% nickel, whereas the Birchtree Mine processed 613,000 t grading 1.39% nickel (Vale S.A., 2014b, p. 38, 42–43). The Thompson operation also smelted concentrates shipped from Vale's mining operation near Voisey's Bay in northern Labrador.

Newfoundland and Labrador.—Vale Newfoundland & Labrador Ltd. extracted 2.32 Mt of ore grading 2.89% nickel and 1.68% copper from its Ovoid Mine near Voisey's Bay that eventually yielded 63,000 t of refined nickel, up from 61,900 t in 2012 but somewhat less than the 68,900 t of 2011. In 2013, Vale Nickel shipped the high-grade nickel concentrate produced at Ovoid to Sudbury, Ontario, and Thompson for smelting and downstream processing (Vale S.A., 2014b, p. 38, 42–43). Vale has been constructing a hydrometallurgical processing plant at Long Harbour, Newfoundland, since April 2009. The $4.25 billion Long Harbour plant was scheduled to begin production of nickel metal rounds in July 2014 using sulfide concentrates from Ovoid and matte from PT Vale Indonesia Tbk. as feed. The pressurized hydrometallurgical process developed for the Long Harbour plant eliminates the traditional step of first smelting the sulfide concentrate. Elimination of this smelting requirement gives the hydrometallurgical process an economic and environmental advantage over the two-step pyrometallurgical process used elsewhere—a process which is typically followed by carbonylation, electrolytic refining, or electrowinning of the sulfide matte (Fluor Corp., 2014; Roberts, 2014, Vale S.A., 2014a). The mine became fully operational in February 2014.

Ontario.—Sudbury has been the leading nickel-producing district in Canada since 1883. Vale Canada's Ontario Division produced 69,400 t of refined nickel in 2013 from its own ores, up from 65,500 t in 2012. The Ontario Division had eight mines operating in 2013. Some of the 69,400 t was recovered from intermediate nickel oxide at the division's Clydach refinery in the United Kingdom. In 2013, Vale Canada completed construction of its new $450 million Totten Mine. The completely renovated, modernized and enlarged mine produced 64,000 t of ore grading 1.84% copper and 1.92% nickel (Vale S.A., 2014b, p. 38–43). The mine became fully operational in February 2014.

In 2012, Glencore Xstrata, Sudbury's other principal producer, mined 1,480,000 t of ore with an average grade of 1.61% nickel and 3.71% copper (Xstrata plc, 2013b, p. 8–9). Equivalent data for 2013 were unavailable. The Strathcona mill was shut down for maintenance during the first quarter of 2013. In 2013, Glencore Xstrata's smelter at Falconbridge produced an estimated 76,000 t of nickel in matte—an alltime high for the facility. All the matte was shipped to the company's Nikkelverk operations in Norway for refining (Glencore Xstrata plc, 2014a, p. 57, 60; 2014b, p. 5, 8–9).

KGHM International Ltd. [a Canadian subsidiary of KGHM Polska Miedź S.A. (Lubin, Poland)] controlled the Levack/Morrison, McCreedy West, and Podolsky Mines, all located within 35 km of Sudbury, and held the mineral rights to the Kirkwood and Victoria properties. In 2013, the company sold ore containing 4,630 t of payable nickel. The Morrison Mine produced 2,860 t, or 62% of the 4,630 t. Another 1,680 t (36%) came from McCreedy West, whereas the remaining 90 t (2%) came from Podolsky (KGHM International Ltd., 2014, p. 6, 8–10, 19).

Noront Resources Ltd. (Toronto) continued to evaluate a cluster of copper-nickel-PGE deposits in the McFaulds Lake District of northern Ontario (52° 46′N, 86° 3′W). The district is located in the James Bay Lowlands and is the site of two massive chromite zones associated with a large ultramafic intrusion—the Ring of Fire. The Provincial government of Ontario was working with the mining industry, local communities, and the Matawa First Nations to develop all-weather roads, a possible rail line, and other infrastructure needed to support mining development (Kral, 2013, p. 22, 24). The Noront copper-nickel project now encompasses three deposits—the original "Eagle's Nest," "Eagle Two," and "AT–12." The Eagle's Nest appears to be a komatiitic deposit (that is, a sulfide deposit interpreted to have formed in a dynamic lava channel or magma conduit). The main zone of the Eagle's Nest has 11.0 Mt of measured and indicated resources averaging 1.78% nickel, 0.98% copper, 3.4 grams per ton (g/t) palladium, and 0.99 g/t platinum. Noront completed an environment impact statement in December (Burgess and others, 2012; p. 3–9, 14–15, 140; Noront Resources Ltd., 2013; 2015, p. 4–8).

Quebec.—Glencore Xstrata's Raglan operation in northern Quebec produced 33,793 t of nickel in concentrate, which was 18% more than the 28,613 t recovered in 2012. Four underground mines were operating at the end of 2013—Katinniq, Kikialik, Mine 2, and Qakimajurq. Glencore Xstrata was preparing to launch 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 Kangiqsujuag, Salluit, and other Nunavimmiut communities. If the Sivumut Project is approved, two new mines—the Donaldson Mine and Mine 14—would be developed, allowing mining to continue until 2032, and conceivably until 2041 (Xstrata plc, 2013a, p. 8; Raglan Mine, 2015; Rogers, 2014).

Royal Nickel Corporation (Toronto) continued to evaluate the Dumont nickel property, about 70 km northwest of Val d'Or. The nickel mineralization was associated with a 700-m-thick mafic-to-ultramafic sill. In July 2013, Ausenco Solutions Canada, Inc. and four other contactors released a joint NI 43–101-compliant technical report on the property. The principal ore minerals were pentlandite [$(Fe,Ni)_9S_8$], heazlewoodite (Ni_3S_2), and awaruite (Ni_3Fe). Blebs of the three minerals sometimes formed agglomerates with one another and were frequently associated with magnetite (Fe_3O_4). The deposit had 1,179 Mt of proven and probable reserves grading 0.27% nickel, putting Dumont on par with the Voisey's Bay deposit in Labrador. (Ausenco Solutions Canada, Inc., 2013, p. 1–1 to 1–7, 7–1 to 7–20; Muinonen, 2014).

China.—China produced large tonnages of conventional ferronickel grades, ranging from 15% to as much as 80% nickel content based on customer end use, plus NPI, a nickel-iron alloy containing less than 15% nickel, for an estimated output exceeding 2.5 Mt gross weight. China's NPI industry

has grown rapidly since 2006. During the past 7 years, the bulk of China's production has shifted from traditional blast furnaces and relatively small-scale electric furnaces to much more efficient RKEF facilities. Because the output of Chinese nickel mines lags far behind domestic demand at the present, the NPI industry has used significant tonnages of lateritic DSO from Indonesia and the Philippines, and to a lesser extent, New Caledonia. The Government of Indonesia was concerned about the increasing exports of DSO to China and enacted a law banning the export of unprocessed ores that would take effect in January 2014. Indonesia's Government hoped that the new law would stimulate construction of RKEF operations, ferronickel smelters, and similar downstream processing facilities in the archipelago. In August 2012, PT Indoferro (Jakarta, Indonesia) commissioned a 450-cubic-meter blast furnace capable of producing 250 Mt/yr of NPI at Cilegon on the island of Java. The lead contractor was China National Machinery Import & Export Corp. (PT Indoferro, 2015). At yearend 2013, Chinese contractors and engineers were designing several other NPI complexes for Indonesian customers (See "Indonesia").

According to the China Nonferrous Metals Industry Association, China produced 480,000 t of nickel contained in NPI in 2013, up from 360,000 t (revised) in 2012 (Nickel Monthly, 2015b, p. 1). NPI from Nei Mongol Autonomous Region and Jiangsu and Liaoning Provinces typically contains 10% to 15% nickel, compared with only 4% to 8% at some operations in Shandong and Shanxi Provinces. At least 11 greenfield NPI plants were in varying stages of construction at yearend 2013. Three of these projects were large-scale RKEF operations—one each in Fujian, Guangdong, and Jiangsu Provinces. Another three projects sintered DSO and then fed the sinter to an electric arc furnace (Nickel Monthly, 2015a, p. 17–19).

At the other end of the spectrum, China produced 206,089 t of nickel in cathode or utility nickel, up from 189,612 t in 2012. Jinchuan Group Co., Ltd. (Jinchang City) was the leading producer, recovering 150,000 t of refined nickel in 2013, up from 135,000 t in 2012. Total domestic output of nickel for 2013 amounted to 278,500 t.

Xinjiang Xinxin Mining Industry Co., Ltd. (Urumqi) continued to explore for nickel and develop nickel sulfide resources in the Xinjiang Uygur Autonomous Region. The company operated the Kalatongke nickel-copper mine in Fuyun County, about 450 km northeast of Urumqi, the regional capital. At yearend, Kalatongke had 18.5 Mt of reserves grading 1.02% copper and 0.61% nickel. Xinjiang Xinxin had three additional nickel-copper mines near Hami, which the company acquired in 2009—Huangshandong, Huangshan, and Xiangshan. The nickel concentrates were converted to matte and sent to the Fukang refinery—also in Xinjiang—for processing into nickel cathode. In 2013, the Fukang refinery produced 10,307 t of nickel cathode and 7,659 t of copper cathode, making Xinjiang Xinxin the second-leading primary nickel producer in China after Jinchuan (Xinjiang Xinxin Mining Industry Co., Ltd., 2014, p. 3–13).

Guatemala.—In October 2012, Cunico Resources N.V. (Amsterdam, Netherlands) acquired Guaxilan, S.A., which held several exploration and exploitation concessions with significant resources of high-grade saprolitic ores in the Cerro Colorado area of Zacapa. Cunico began exporting the lateritic ores to the Greek port of Thessaloniki, where they were railed to Kosovo and Macedonia. Cunico was the leading producer of ferronickel in Europe and had mines and ferronickel smelters in both Kosovo and Macedonia. The first ores shipped from the Guaxilan open pit operation reportedly went to the ferronickel smelter at Kavadarci, Macedonia, which was operated by Feni Industries—a wholly owned subsidiary of Cunico. The Guaxilan ores were blended with a variety of lateritic ores mined in the Balkans before being smelted at Kavadarci to produce ferronickel granules. If the project and shipping prove economic, the Guaxilan ore would largely replace ore from Cunico's Rzanovo Mine at Kozuf Mountain, 40 km south of Kavadarci near the Greek border (Cunico Resources N.V., 2015).

Indonesia.—In mid-2012, the Government of Indonesia reminded Antam and other companies mining nickel laterites that new quotas would be introduced soon as part of a comprehensive national policy to sharply limit exports of all DSO. Indonesia's Government wanted foreign consumers to construct state-of-the-art ferroalloy and NPI facilities in the archipelago. However, a shortage of hydroelectric powerplants and other renewable-energy-based utilities limited the number of sites suitable for greenfield electric-furnace-based smelters. The new regulations, originally enacted in 2009 as Law No. 4, were scheduled to come into force on January 12, 2014. The regulations halted all sales of Indonesian DSO to overseas producers of ferronickel and NPI, as well as to other foreign customers. The ban also applied to bauxite and chromite (Jensen and Supriatna, 2012; Els, 2014; Jensen, 2014).

In 2013, foreign buyers sharply increased their purchases of DSO from Indonesia and the Philippines in anticipation of the ban. Indonesia exported 64.8 Mt of nickel ore, of which 58.6 Mt went to China, 2.0 Mt to Japan, 1.6 Mt to Australia, 1.5 Mt to Ukraine, and 1.1 Mt to other countries. This represented an increase of 34% over the 48.4 Mt in 2012 (International Nickel Study Group, 2014, p. B–18; 2015, p. B–17).

Antam was modernizing and expanding its ferronickel complex at Pomalaa in anticipation of the imminent ban and tax on exports of DSO. The expansion was expected to be completed in October 2015. Antam mined 11.52 Mt (wet) of various laterite ores, surpassing its alltime high of 9.43 Mt in 2012. Three mines shipped ore in 2013: Pomalaa (Southeast Sulawesi), Pakal Island (North Maluku), and Tanjung Buli (North Maluku). About 86% of the production was DSO for export—primarily to Australia, China, Eastern Europe, and Japan. Antam produced 18,249 t of nickel in ferronickel, slightly less than the 18,372 t in 2012. Approximately 85 to 90 wet metric tons of saprolite ore averaging 1.8% nickel were needed to produce 1 t of nickel contained in ferronickel. Antam's three smelters at Pomalaa had a combined capacity of 20,000 t/yr of nickel in ferronickel (in the form of ingot and shot averaging 19% to 21% nickel) (PT Aneka Tambang Tbk., 2014, p. 30–34, 96–97, 101, 120–121, 164, 168, 226–229).

PT Vale Indonesia Tbk. (PTVI) (formerly PT International Nickel Indonesia Tbk.) mined 4.37 Mt of ore averaging 2.00% nickel from its Sorowako concessions on Sulawesi, as measured by the amount of product delivered to the company's

smelter from its adjoining dryer and reduction kiln complex. The smelter produced 75,802 t of nickel in matte for export to Japan, up by 7% from that in 2012. In past years, high-sulfur fuel oil was used to operate the three rotary dryers and five reduction kilns. However, over time fuel oil had become a major expense for the company. In the fourth quarter of 2013, PTVI completed the first phase of a two-phase coal conversion project begun in 2011. All three dryers were converted to operate on pulverized coal from local sources. The reduction kilns were to be converted to coal during the second phase of the project. The smelter had four electric furnaces and three Pierce-Smith converters. Vale Canada had a 59% interest in PTVI. The next largest shareholder was Sumitomo Metal Mining Co. Ltd., with 20%. All of the matte produced at Sorowako was shipped for further processing to downstream Asian operations of Sumitomo and Vale and was exempt from the 2014 ban. At yearend 2013, PT Vale had 127.5 Mt of proven and probable reserves averaging 1.79% nickel (PT Vale Indonesia Tbk., 2014, p. 10, 27, 29, 47–48, 55, 64, 77–78, 130).

Ibris Nickel Pte. Ltd. (Singapore) and smaller, locally owned mining companies, like PT Mobi Jaya Persada (Dampala), were especially concerned about the controversial export ban. Ibris, the third-leading nickel mining company in Indonesia, employed about 1,400 workers at its 2-Mt/yr mine in North Konawe, Southeast Sulawesi. All of the North Konawe ore production was exported in 2013. On January 1, 2014, Ibris put its North Konawe mining operations on hold owing to uncertainty over the ban (Jensen, 2014; Jensen and Asmarini, 2014).

The Solway Investment Group Ltd. had been evaluating Indonesian resources of lateritic ore as possible feed for its Pobugski (or Pobuzhskiy) ferronickel plant in Ukraine when the Government of Indonesia issued its reminder. The impending ban encouraged Solway to focus its attention on the Maba ores of Halmahera Island, North Maluku. The Maba district had more than 100 Mt of resources that graded 1.7% nickel and also had a favorable silica-to-magnesia ratio. Solway was considering constructing a ferronickel plant on Halmahera in anticipation of the ban. The proposed Aquila plant would have a production capacity of 38,000 t/yr of nickel in ferronickel, and be supported by a proposed 320-megawatt (MW) powerplant that would employ circulating fluidized bed technology and burn coal from Aquila's concession in West Papua Province (Solway Investment Group Ltd., undated).

ERAMET, in contrast, postponed plans to construct a nickel mining and hydrometallurgical processing complex at Weda Bay on Halmahera Island until the global market for nickel improved. PT Weda Bay Nickel (Jakarta) was a joint venture of ERAMET (60%), Mitsubishi Corp. (27%), Antam (10%), and Pacific Metals Co. (3%). The hydrometallurgical plant proposed for phase 1 of the project was to have had an initial design capacity of 35,000 t/yr of nickel (ERAMET Group, 2014, p. 5, 12, 18–19, 24, 39).

Madagascar.—The $5.5 billion Ambatovy mining and hydrometallurgical complex was commissioned in the third quarter of 2012. The lateritic ore was leached with hot sulfuric acid in autoclaves to produce a mixed sulfide intermediate of cobalt and nickel. In 2013, Ambatovy produced 29,248 t of nickel and cobalt in mixed sulfides. The mixed sulfides were processed at the refinery in Toamasina, where the cobalt and nickel were separated from one another by solvent extraction. In 2013, the refinery produced 25,148 t of nickel metal briquettes and 2,083 t of cobalt metal briquettes and powder. When fully operational, Ambatovy would be capable of producing 60,000 t/yr of nickel metal and 5,600 t/yr of cobalt metal. The complex was expected to be one of the largest lateritic mining, processing, and refining operations in the world (Sherritt International Corp., 2014, p. 5–9, 38–39).

New Caledonia.—Société Le Nickel (SLN) has been mining nickel on Grande Terre since 1880 and is 56% owned by the ERAMET Group. In 2013, SLN produced 39,700 t of nickel in ferronickel at its Doniambo smelter near Noumea. The nickel content of SLN's ferronickel shot ranged from 20% to 27%. The smelter also produced 13,279 t of nickel in matte, which was shipped to ERAMET's Sandouville refinery in France for conversion into LME-grade metal and chemicals (Direction de l'Industrie, des Mines et de l'Energie, 2015, p. 2; ERAMET Group, 2015a, p. 23; International Nickel Study Group, 2015, p. B–25).

At yearend 2013, Vale Nouvelle-Calédonie SAS (VNC) continued to ramp up production at its new 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 1.86 Mt of lateritic ore averaging 1.36% nickel to the hydrometallurgical plant. The plant produced 7,557 t of nickel in nickel hydroxide cake averaging 16% nickel and 7,911 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 for further processing. The nickel oxide was sent to Vale's refineries at Dalian, China, and Kaohsiung, Taiwan, for conversion into utility nickel. At yearend 2013, VNC had 124 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; Vale S.A., 2014b, p. 39–43, 65).

In April, Koniambo Nickel SAS poured the first ferronickel at its $5 billion mining and smelting project in the North Province. The project was a joint venture of Glencore Xstrata plc (49% equity) and Société Minière du Sud Pacifique S.A. (SMSP) (51% equity). Koniambo Nickel mined saprolitic ore from a complex of open pits in the Koniambo Massif and used an overland conveyor system to haul the ore about 11 km to a new pyrometallurgical smelter near the private, deepwater port of Vavouto. The Vavouto complex was located about 25 km northwest of the North Province capital of Kone and included a powerplant with two 135-MW coal-fired boilers plus a seawater desalination plant that supplied both process and potable water. Koniambo produced 1,400 t of nickel in ferronickel during rampup in 2013. The smelter had a design capacity of 60,000 t/yr of nickel in ferronickel shot. The nonfriable shot averaged 35% nickel, 63% iron, and 0.9% cobalt. At yearend 2013, the Koniambo Mine had 61.5 Mt of proven and probable reserves averaging 2.36% nickel

(Swanepoel, 2013; Xstrata Nickel, 2013; Glencore Xstrata plc, 2014b, p. 5; Koniambo Nickel SAS, 2013, 2014a, b).

The Nakéty Mine Centre, a subsidiary of the SMSP Group, continued to supply the ferronickel plant at Gwangyang, Republic of Korea, with saprolite ore. The Gwangyang plant, operated by Société du Nickel de Nouvelle-Calédonie et Corée Pty. Ltd. (SNNC), is a joint venture of SMSP and the South Korean stainless steelmaker POSCO (formerly Pohang Iron & Steel Co. Ltd.). The SNNC plant has a production capacity of 30,000 t/yr of nickel in ferronickel.

Papua New Guinea.—Metallurgical Corporation of China Ltd. (MCC) continued to ramp up production at the Ramu project near Madang. The $2.1 billion nickel-cobalt project was a joint venture of a Chinese consortium led by MCC (85%), the Government of Papua New Guinea and local landowners (6%), and Highlands Pacific Ltd. (9%). The Basamuk processing plant was designed to produce 78,000 t/yr (dry) of mixed nickel-cobalt hydroxide containing 31,200 t of nickel and 3,300 t of cobalt. In 2013, the project produced 29,736 t (dry) of mixed hydroxide containing 11,369 t of nickel and 1,013 t of cobalt. The project was expected to achieve full production in 2016 (Gooding, 2015, p. 10–14; Highlands Pacific Ltd., 2015a, p. 8–9, 13–14; 2015b).

In July 2013, Highlands Pacific used augers to drill 20 reconnaissance holes on the northwestern half of Normanby Island, where nickel laterites have developed over Cretaceous ultramafic rocks (Gooding, 2015, p. 18–19).

Russia.—About 81% of Norilsk's sales of marketable nickel came from its Russian operations. The other 19% was generated by the company's holdings in Finland (17%) and Botswana (2%). Norilsk's Australian subsidiary produced 2,826 t of nickel in concentrate from ore mined at Lake Johnston, southwest of Kalgoorlie, before the Lake Johnston operation was mothballed in the second quarter of 2013. The Lake Johnston concentrate was shipped to Norilsk's Harjavalta refinery in Finland for further processing. Norilsk's operations on the Kola and Taimyr Peninsulas had a combined output of 231,798 t of nickel metal—about 97% of Russia's primary nickel output for the year. Norilsk's Polar Division on the Taimyr Peninsula produced 122,700 t of refined nickel, while Kola MMC's operations near the Finnish border produced 109,100 t. Norilsk's two 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, 2014, p. 42–45, 62–69, 81–82, 227).

In July 2013, OAO Mechel (Moscow) put its smelter on care-and-maintenance status for an indefinite period of time, causing employment at Orsk to drop from 2,929 at yearend 2012 to only 274. Mechel had an 84.1% interest in the operation at yearend 2013 and retained its Shevchenko nickel silicate deposit in northwestern Kazakhstan. The Shevchenko subsoil license was scheduled to expire in March 2017 (OAO Mechel, 2014, p. 61, 67, 112–114, 151–153, 245–248).

Mechel's Chelyabinsk Metallurgical Plant and other steel operations consumed about 4,000 t of nickel during 2013 to make stainless steel and other specialty steels. The nickel was sourced from JSC "Ufaleynickel" (Verkhniy Ufaley) and ZAO Normetimpeks (a Moscow-based trading company involved in the sale of fuels, metals, and ores) (OAO Mechel, 2014, p. 99–114, 245–248). Ufaleynickel reportedly was sold to an alliance of four Cypriot offshore firms and had been supplying granulated nickel to Swiss metals trader Alpicom S.A. since mid-2012 (Interfax, 2012, 2013c).

In May 2012, the Russian Federal Subsurface Resources Agency held a tender to develop the Yelanskoye and Yelkinskoye copper-nickel sulfide deposits in Voronezhskaya Oblast'. Since then, the project has encountered resistance from environmental activists, local residents, and some scientists from academia. At yearend 2013, six drilling rigs were reportedly operating at Yelanskoye. In early 2014, Norilsk and UMMC were considering working together on the project (OJSC MMC Norilsk Nickel, 2011; Rusmininfo Ltd., 2012; Interfax, 2013b, d; Moscow Times, The, undated)

In November 2012, Russian authorities extended the exploration license of Amur Minerals Corp. (Khabarovsk, Russia, and Tortola, British Virgin Islands) for another 2 years. The British-backed company has been studying and assessing the Kun-Manie nickel-copper deposits in the far northeast corner of Amur Oblast' since 2006. In March 2013, the Amur regional authorities decided to include the Kun-Manie project in the government's socioeconomic development program for the Russian Far East and accepted Amur Minerals into the program. The company's application for a mining license was moving through the regulatory system. Measured and (or) indicated reserves have been determined for four areas: Gorny, Ikenskoe, Maly Kurumkon, and Vodorazdelny. In July 2013, measured reserves totaled 15.8 Mt averaging 0.52% nickel and 0.13% copper. Indicated reserves totaled 34.3 Mt averaging 0.55% nickel and 0.15% copper. If inferred resources are included, these figures equate to 341,000 t of nickel and 95,000 t of copper (Amur Minerals Corp., 2013; Amur Minerals Corp. and its subsidiaries, 2014; Interfax, 2013a).

Tanzania.—IMX Resources Ltd. (West Perth, Western Australia, Australia) has been exploring for nickel in two districts of Tanzania—at the Nachingwea property (180 km west of the Port of Mtwara) and at the Mibango property (10 km east of Lake Tanganyika). In September, MMG Exploration Holdings Ltd. (Kowloon, Hong Kong) entered into a joint venture with IMX Resources and agreed to both manage and fund the ongoing drilling program at Ntaka Hill, in the northeastern area of the Nachingwea property. In exchange, MMG was initially given a 14.7% interest in the Nachingwea project. IMX Resources had already identified 20.3 Mt of measured and indicated resources at Ntaka Hill that averaged 0.58% nickel, 0.13% copper, and 0.02% cobalt. In December, the joint venture discovered a new zone of nickel sulfide mineralization at Ntaka Hill—the P Zone—400 m east of the Zeppelin and Sleeping Giant ore bodies (IMX Resources Ltd., 2013, undated).

Vietnam.—In mid-2013, Ban Phuc Nickel Mines LLP (BPNM—Hanoi, Vietnam) completed development work at its underground mine in Son La Province after a hiatus of 5 years. On June 29, the mine was commissioned at a ceremony by officials of both the Central and Provincial governments. Ban Phuc is the first nickel mine in Vietnam and is located in the Son Da Rift Zone, 160 km west of Hanoi. The nearby beneficiation

plant began producing concentrates on July 2 and was expected to produce 6,600 t/yr of nickel, 3,300 t/yr of copper, and 200 t/yr of cobalt contained in concentrates after rampup was completed in 2014. Commercial production of concentrates began in November 2013, with all of the output reportedly going to Jinchuan Group Co., Ltd. as part of a long-term offtake agreement. Asian Mineral Resources Ltd. (AMR—Toronto) has a 90% interest in BPNM. The remaining 10% is held by a local Vietnamese partner—Son La Mechanical Engineering Joint Stock Co. (Asian Mineral Resources Ltd., 2013a). In late December, the Ministry of Natural Resources and Environment awarded BPNM a new 4-year exploration license covering an area of 49.7 square kilometers in and along the Son Da Rift Zone (Asian Mineral Resources Ltd., 2013b, 2014, 2015).

Outlook

Nickel consumers in the United States are expected to be dependent on foreign sources of refined metal and ferronickel for at least the next 25 years, even if all four of the current copper-nickel mining projects in the Lake Superior region come to fruition. The ongoing expansion of nickel laterite mining operations in Brazil, Guatemala, Indonesia, New Caledonia, the Philippines, and other tropical countries will help meet the increasing demand for nickel worldwide. The nickel output from Vale's state-of-the-art leach facility in New Caledonia and the company's new Long Harbour plant in Newfoundland is expected to satisfy the midterm rise in global demand projected after 2016. Long-range forecasts of increasing usage in Asia have encouraged parastatal companies in China to fund the development of greenfield laterite mines in Burma, Indonesia, and Papua New Guinea. Asian, European, and North American companies are seriously considering funding large-scale laterite projects in the Philippines, the Solomon Islands, and Tanzania. At least two exploration companies are showing renewed interest in the nickel mineralization of Côte d'Ivoire, especially deposits near Biankouma and Yoroudougou.

Sulfide mines approaching the end of their productive lives because of dwindling reserves and high operating costs continue to be replaced. Exploration for nickel sulfides is underway in several parts of the Arctic, including the Far North of Alaska, Baffin Island and other parts of Nunavut, and the Yukon. North American Nickel has launched an aggressive exploration program at its Maniitsoq property in southwestern Greenland, following the discovery of high-grade pentlandite-chalcopyrite mineralization at Imiak Hill. Developments of high-grade sulfide deposits like Imiak Hill, however, are becoming less frequent because the deposits are harder to find and are located farther from traditional shipping routes. These new projects are more costly to finance owing to their remoteness, stricter environmental regulations, and increased technical complexity. As a result of advances in bioengineering, large-tonnage, low-grade polymetallic sulfide ore deposits like those at Sotkamo, Finland, previously passed over, are now amenable to bioheap leaching.

Preliminary data suggest that world mine production in 2014 was slightly less than that of 2013, largely as the result of cutbacks in Australia, Brazil, and Indonesia.

Concerns about global warming and associated climate changes, together with high oil prices, have encouraged research, development, and construction in the renewable energy sector. The retrofitting of coal-fired powerplants to reduce CO_2 emissions remains a national issue. Many of the older coal-fired plants do not meet current environmental standards, cannot be economically renovated, and are scheduled to be retired. State-of-the-art powerplants fired by natural gas are expected to replace some of these coal-based facilities.

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. To meet demand, utilities will need to build more generating capacity, irrespective of whether the plants operate on fossil fuels, renewable energy (geothermal, solar, or wind), or nuclear fuels (safer, fourth-generation nuclear reactors). All of this capacity would require large tonnages of nickel-bearing stainless steel and superalloys (U.S. Energy Information Administration, 2014a, p. MT–16 to MT–23).

Demand for nickel in the transportation sector is also expected to increase. Chinese, European, and North American use of nickel- and cobalt-base superalloys is expected to escalate between 2013 and 2020, largely because of increasing demand for new jet aircraft that have more-fuel-efficient engines. Boeing forecasts an average growth rate of 4% to 5% per year for global passenger and cargo air traffic between 2013 and 2033. An estimated 36,800 new airplanes would have to be built during the 20-year period to meet demand. Significantly higher gasoline prices could encourage the replacement of conventional automobile steel frames with lighter ones fabricated from stronger stainless steel. 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 (Boeing Co., The, 2014, p. 24–29; Tinseth, 2014, p. 10–26).

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TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons of contained nickel unless otherwise specified)

		2009	2010	2011	2012	2013
United States:						
Secondary recovery from purchased scrap:						
From ferrous scrap		72,100	73,300	77,400 r	80,400	77,600
From nonferrous scrap		7,730	8,640	11,400 r	12,100 r	11,200
Shipments of purchased scrap[2]		152,000	139,000	132,000 r	130,000 r	124,000
Exports:						
Primary		7,030	12,600	12,400	9,100	10,600
Secondary		90,000	80,300	64,800	59,800	61,200
Imports for consumption:						
Primary		99,900	129,000	138,000	133,000	126,000
Secondary		17,700	23,800	21,300	22,300	26,300
Consumption:						
Reported:						
Primary		83,100	100,000 r	110,000 r	114,000 r	114,000
Secondary, purchased scrap		79,800	81,900	88,800 r	92,400 r	88,800
Total		163,000	182,000 r	199,000 r	207,000 r	203,000
Apparent, primary		93,800 r	114,000 r	125,000 r	125,000 r	110,000
Apparent primary plus reported secondary		174,000 r	196,000 r	213,000	218,000 r	199,000
Stocks, yearend:						
Producers and traders		5,490	6,240	6,610 r	6,380 r	9,730 p
Consumer, primary		8,910 r	10,700 r	11,400 r	10,100 r	12,000
Consumer, secondary		5,520	6,150	6,640	6,550 r	6,510
Total		19,900 r	23,100 r	24,700 r	23,000 r	28,300
Price, cash, London Metal Exchange:						
Average annual	dollars per metric ton	14,649	21,804	22,890	17,533	15,018
Average annual	dollars per pound	6.645	9.890	10.383	7.953	6.812
Price, Type 304 stainless steel scrap, gross weight:[3]						
Average annual	dollars per metric ton	1,462	2,200	2,276	1,859 r	1,574
Average annual	dollars per long ton	1,486	2,235	2,312	1,889 r	1,599
World, mine production		1,410,000 r	1,710,000 r	2,320,000 r	2,410,000 r	2,660,000

pPreliminary. rRevised.
[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]Derived from the monthly averages of the consumer buying price in Pittsburgh, PA, as published in American Metal Market (AMM). 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)

	2012	2013
Kind of scrap:		
Aluminum-base[2]	2,110	2,100
Copper-base	1,230 r	1,080
Ferrous-base[3]	80,400	77,600
Nickel-base	8,720 r	8,030
Total	92,400 r	88,800
Form of recovery:		
Aluminum-base alloys	2,110	2,100
Copper-base alloys	2,050 r	1,500
Ferrous alloys	83,000 r	80,100
Nickel-base alloys	5,270	5,090
Total	92,400 r	88,800

rRevised.

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

[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	2012	2013
Primary:		
Metal	97,200 r	95,900
Ferronickel	14,900	15,100
Oxide and oxide sinter[2]	257	209
Chemicals[3]	511	791
Other	1,270 r	1,800
Total	114,000 r	114,000
Secondary, scrap[4]	92,400 r	88,800
Grand total	207,000 r	203,000

rRevised.

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

(Metric tons of contained nickel)

Use	2013								Grand total in 2012
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total	
Consumption reported:									
Cast irons[2]	54	--	--	--	2	56	202	258	2,130
Chemicals and chemical uses	1,390	--	(3)	622	--	2,020	--	2,020	1,670
Electric, magnet, expansion alloys	216	W	--	34	--	250	(3)	250	2,090 r
Electroplating, sales to platers	8,430	--	--	W	(3)	8,430	--	8,430	9,330 r
Nickel-copper and copper-nickel alloys	W	--	1	--	22	23	1,260	1,280	5,530 r
Other nickel and nickel alloys	16,300	80	5	--	43	16,400	W	16,400	22,600 r
Steel:									
Stainless and heat resistant	33,800	12,900	81	--	72	46,800	78,300	125,000	126,000 r
Alloys, excludes stainless	3,830	96	--	--	--	3,930	1,640	5,560	5,080 r
Superalloys	25,000	120	--	1	1,430	26,600	W	26,600	26,600 r
Other[4]	6,890	1,980	121	134	228	9,350	7,430	16,800	5,550 r
Total	95,900	15,100	209	791	1,800	114,000	88,800	203,000	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	2012	2013
Primary:		
Metal	8,870 r	10,700
Ferronickel	1,010	1,010
Oxide and oxide sinter	24	24
Chemicals[2]	61 r	98
Other	99 r	153
Total	10,100 r	12,000
Secondary, scrap	6,550 r	6,510
Grand total	16,600 r	18,500

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	2012		2013	
	Quantity (metric tons of contained nickel)	Value (thousands)	Quantity (metric tons of contained nickel)	Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	1,240	$23,800	1,540	$24,900
Ferronickel	182	5,190	479	8,040
Powder and flakes	1,350	54,600	1,590	58,800
Metallurgical-grade oxide[2]	1,700	17,900	2,210	17,400
Chemicals:				
Catalysts[3]	3,410	247,000	3,820	269,000
Salts[4]	1,230	23,000	910	18,900
Total	9,100	372,000	10,600	397,000
Secondary:				
Stainless steel scrap	46,800	804,000	48,300	743,000
Waste and scrap[5]	13,000	121,000	12,900	110,000
Total	59,800	925,000	61,200	853,000
Grand total	68,900	1,300,000	71,800	1,250,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	326	10,300	368	11,600
Sheets, strip, foil	356	12,400	304	11,700
Tubes and pipes	138	2,360	56	1,770
Total	820	25,100	728	25,000
Alloyed, gross weight:				
Unwrought alloyed ingot	5,500	149,000	5,100	113,000
Bars, rods, profiles, wire	21,800	796,000	19,800	704,000
Sheets, strip, foil	10,700	390,000	11,600	384,000
Tubes and pipes	2,310	134,000	2,100	131,000
Other alloyed articles	3,590	366,000	3,810	425,000
Total	43,900	1,830,000	42,400	1,760,000

[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 be 50% nickel; stainless steel scrap, 7.5%.

Source: U.S. Census Bureau.

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

(Metric tons of contained nickel)[2]

	2013									
Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2012	Wrought nickel in 2013[4]
Australia	--	3	--	(5)	837	1	23	864	245	3
Belgium	--	10	--	46	10	306	159	531	930	2
Brazil	183	40	--	(5)	--	19	527	769	291	8
Canada	50	175	70	1,640	8,290	1,810	754	12,800	14,300	30
China	31	294	1	231	7	7,670	588	8,820	8,250	98
Colombia	27	17	--	--	--	3	10	57	97	11
Finland	--	--	--	--	--	(5)	4	4	477	1
France	--	6	(5)	(5)	1	11	30	48	82	14
Germany	1	283	6	25	21	179	59	574	942	48
Hong Kong	60	11	--	(5)	9	362	34	476	592	5
India	--	66	--	(5)	78	4,070	281	4,500	4,700	14
Italy	--	2	393	--	(5)	1	10	406	281	20
Japan	--	96	--	4	1,720	2,110	133	4,060	3,370	15
Korea, Republic of	1	67	(5)	3	10	7,270	149	7,500	5,790	53
Malaysia	(5)	2	--	1	--	82	125	210	296	17
Mexico	1,100	113	--	16	2	157	333	1,720	1,460	81
Netherlands	72	19	2	--	1,000	408	266	1,770	1,520	5
Pakistan	--	(5)	--	--	--	5,860	(5)	5,860	3,130	--
Singapore	1	112	--	3	4	77	25	222	285	32
South Africa	--	10	--	1	--	--	93	104	81	--
Spain	--	2	--	--	(5)	416	1	419	1,240	1
Sweden	--	16	--	--	255	216	(5)	487	508	6
Taiwan	14	50	4	--	124	16,100	155	16,400	16,400	47
Thailand	--	55	(5)	--	--	531	12	598	941	1
United Kingdom	1	49	1	196	476	62	129	914	1,320	23
Vietnam	--	(5)	--	--	18	338	--	356	267	10
Other	7	89	--	42	13	323	827	1,300	1,130 r	180
Total	1,540	1,590	477	2,210	12,900	48,300	4,730	71,800	68,900	725

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 sulfate, 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 "2013, 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	2012		2013	
	Quantity (metric tons of contained nickel)	Value (thousands)	Quantity (metric tons of contained nickel)	Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	111,000	$2,010,000	104,000	$1,630,000
Ferronickel	13,000	228,000	13,700	212,000
Powder and flakes	5,210	131,000	5,690	120,000
Metallurgical-grade oxide[2]	868	18,500	687	14,500
Chemicals:				
Catalysts[3]	1,590	111,000	1,590	92,800
Salts[4]	952	19,100	1,010	20,000
Total	133,000	2,520,000	126,000	2,090,000
Secondary:				
Stainless steel scrap	11,700	236,000	17,000	211,000
Waste and scrap[5]	10,600	209,000	9,350	149,000
Total	22,300	445,000	26,300	359,000
Grand total	155,000	2,960,000	153,000	2,450,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	669	16,500	274	8,070
Sheets, strip, foil	600	16,700	464	13,300
Tubes and pipes	174	5,670	120	4,330
Total	1,440	38,800	859	25,700
Alloyed, gross weight:				
Unwrought alloyed ingot	12,200	237,000	10,900	221,000
Bars, rods, profiles, wire	11,400	344,000	10,300	273,000
Sheets, strip, foil	3,650	91,200	2,930	68,700
Tubes and pipes	1,590	91,000	2,000	165,000
Other alloyed articles	1,350	143,000	1,810	165,000
Total	30,100	906,000	27,900	892,000

[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 be 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]

(Metric tons of contained nickel)[2]

	2013									
Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2012	Wrought nickel in 2013[4]
Australia	10,700	365	--	644	138	(5)	--	11,800	18,600	--
Belgium	--	135	--	1	8	(5)	154	298	274	--
Brazil	3,780	--	671	--	182	4	4	4,640	4,900	--
Canada	56,400	3,400	159	20	1,970	7,670	268	69,900	63,300	5
China	619	28	--	--	401	4	14	1,070	1,030	26
Colombia	--	--	3,240	--	1	3	--	3,240	4,580	--
Dominican Republic	--	--	2,430	--	5	11	--	2,440	1,930	--
Finland	7,600	101	--	--	--	--	263	7,970	9,700	--
France	788	13	--	--	864	--	413	2,080	3,210	246
Germany	--	110	--	(5)	626	1	277	1,010	1,060	392
Indonesia	--	--	250	--	10	--	--	260	17	--
Israel	--	11	--	--	25	2	--	38	189	(5)
Italy	--	(5)	--	--	57	--	1	58	145	(5)
Japan	378	57	--	6	575	23	181	1,220	1,440	25
Madagascar	3,140	--	--	--	--	--	--	3,140	--	--
Mexico	--	4	--	7	953	9,090	23	10,100	4,670	(5)
Netherlands[6]	3	--	23	--	--	--	413	439	526	1
New Caledonia	--	--	4,160	--	--	--	--	4,160	2,950	--
Norway	10,600	--	191	--	--	--	--	10,800	11,200	--
Russia	9,030	360	--	--	10	--	(5)	9,400	18,200	(5)
South Africa	260	471	6	--	--	--	--	737	553	--
Spain	--	(5)	--	--	33	(5)	2	35	73	--
Taiwan	--	--	--	--	168	10	5	183	301	--
Ukraine	--	--	2,530	--	--	--	--	2,530	--	--
United Kingdom	325	619	--	2	2,430	60	166	3,600	4,150	50
Other	20	13	11	7	893	109	419	1,470	1,960 r	112
Total	104,000	5,690	13,700	687	9,350	17,000	2,600	153,000	155,000	859

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 "2013, 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]	2009	2010	2011	2012	2013
Albania, laterite ore[e]	1,000	3,000	3,000 [r]	2,000 [r]	2,000 [p]
Australia, ores and concentrate[4]	165,000	170,100 [r]	215,000 [r]	246,000	234,234
Botswana, ore milled	28,595	24,931 [r]	15,675	17,948	22,848 [p]
Brazil, ore	41,059	108,983	131,673	139,230	104,829 [p]
Burma, ore[e, 5, 6]	10	--	800	5,000	9,300 [p]
Canada, concentrate	135,037	160,063	219,025	211,701 [r]	223,295
China[e]	84,800	79,600 [r]	89,800 [r, p]	93,300	107,000
Colombia, laterite ore[e]	79,900 [r]	76,200 [r]	76,000 [r]	84,000	84,700
Cuba, recoverable laterite:[e]					
Limonitic	32,100	32,500	38,100	35,700	34,500
Serpentinic	37,900	37,200	34,400	32,500	31,500
Total	70,000	69,700	72,500	68,200	66,000
Dominican Republic, laterite ore	500	--	21,693	25,590	15,825
Finland, concentrate[7]	4,400 [r]	29,448	63,209	46,755	46,000 [e]
Greece, laterite ore	10,203	16,345	21,710	21,980 [r]	19,100 [e]
Guatemala, laterite ore	--	--	--	2,400 [r, p, 8]	10,200 [e]
Indonesia, laterite ore[9]	202,800	300,800 [r]	564,400 [r]	648,400 [r]	834,200
Kazakhstan, laterite ore[e]	500	500	500	450	450
Kosovo, laterite ore	10,423 [r]	9,081 [r]	7,728 [r]	4,436 [r]	7,606
Macedonia, ferronickel produced[10]	11,762 [r]	14,413	17,292	19,427	20,001
Madagascar, laterite ore	--	2,000 [e]	5,900	8,365 [r]	29,248
Morocco, nickel sulfate	733	317	217	288 [r]	175
New Caledonia, ore	95,649 [r]	131,309 [r]	128,732 [r]	131,693 [r]	164,406 [p]
Norway, concentrate	336 [r]	351	339	351	335
Papua New Guinea, ore	--	--	--	5,283 [r, 11]	11,369 [11]
Philippines:					
Laterite ore[12, 13]	122,709 [r]	153,679 [r]	296,569	293,731	289,613
Concentrate[14]	17,035 [r]	19,312 [r]	22,794	23,890	26,020
Total	139,744 [r]	172,991 [r]	319,363	317,621	315,633
Russia, marketable mine production:					
Laterite ore[15]	32,298 [r]	41,184 [r]	41,777	28,210	27,500 [e]
Sulfide concentrate[16]	229,493	228,093	225,616	217,085	215,000 [e]
Total	261,791 [r]	269,277 [r]	267,393	245,295	243,000 [e]
South Africa, concentrate	34,605	39,960	43,321	45,945	51,208
Spain, concentrate[17]	8,035	5,402 [r]	--	2,397 [r]	7,564
Turkey, laterite ore[e]	1,199 [r, 18]	1,900 [r]	4,300 [r]	3,490 [r]	3,500
United States, concentrate	--	--	--	--	4,090 [19]
Venezuela, laterite ore	13,200 [r]	11,400	19,500	6,060	6,000 [e]
Vietnam, concentrate	--	--	--	335	6,932
Zambia, concentrate[20]	280 [e]	2,482	2,724	--	--
Zimbabwe, concentrate	4,858	6,200 [e]	7,992	7,899	14,058
Total, grand	1,410,000 [r]	1,710,000 [r]	2,320,000 [r]	2,410,000 [r]	2,660,000
Of which:					
Concentrate[21]	434,000 [r]	491,000 [r]	585,000	556,000 [r]	595,000
Ore and ore milled[22]	165,000 [r]	265,000 [r]	277,000 [r]	299,000 [r]	313,000
Laterite ore	545,000 [r]	686,000 [r]	1,140,000 [r]	1,200,000 [r]	1,400,000
Ferronickel produced	11,800 [r]	14,400	17,300	19,400	20,000
Nickel sulfate	733	317	217	288 [r]	175
Unspecified and (or) undifferentiated[23]	250,000 [r]	250,000 [r]	305,000 [r]	339,000 [r]	341,000

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

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

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

[3]North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Includes data available through October 16, 2015.

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

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

[5]Burma's new Tagaung Taung Mine is a joint project of the Government of Burma, China's Taiyuan Iron & Steel, and the China Nonferrous Metal Mining Group (CNMC). The joint venture officially began recovering laterite ore on March 27, 2011. The nickel content of the ore mined and the nickel content of ferronickel produced were reported by the Government.
[6]Numbers have been adjusted to take into account data received from individual company sources as well as trade statistics.
[7]The gross weight of concentrates processed in Finland from domestic ores was, in metric tons, as follows: 2009—43,000 (estimated); 2010—43,151; 2011—87,974; 2012—99,089; and 2013—137,911.
[8]In 2012, Cunico Resources Group N.V. acquired Guaxilan, S.A. and began mining high-grade saprolitic ores for export to Eastern Europe. Solway Investment Group Ltd. was also active in Guatemala and began upgrading the long-dormant Fenix Mine and ferronickel plant west of El Estor.
[9]Includes a small amount of cobalt that was not recovered separately.
[10]Cunico Resources Group extracts nickel ore from its open pit Rzanovo Mine and transports the ore by conveyor to its FeNi Industries pyrometallurgical facility in Kavadarci. At the Kavadarci plant, the Rzanovo ore is blended with higher grade imported ores from Albania, Indonesia, New Caledonia, and Turkey to optimize production.
[11]In 2012, the Ramu joint venture began piping slurried ore from the new Kurumbukari Mine to the treatment plant at Basamuk for leaching in autoclaves.
[12]Source: Philippines Mines and Geosciences Bureau. Significant discrepancies exist between two data series owing to a number of factors. These factors include (1) end-of-year delays and carryovers; (2) excess water absorption on exposed landing craft vessels and barges; and (3) possible irregularities in submitting customs documents, with regard to country of origin or type of ore.
[13]The bulk of the ore production is unprocessed, or minimally processed, direct-shipping ores.
[14]Nickel content of concentrate produced at Rio Tuba in 2009–13 by Coral Bay Nickel Corp.
[15]Nickel content of ore mined in the Ural Mountains region.
[16]Nickel content of concentrate produced on the Kola and Taimyr Peninsulas.
[17]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.
[18]Reported figure.
[19]In 2013 Lundin Mining Co. began recovering nickel-copper ore from the Eagle Mine in Michigan. The concentrator at the Humboldt mill, however, did not begin processing the ore until the third quarter of 2014. The nickel content of the ore was 4,093 metric tons.
[20]Albidon Limited concentrates were shipped to Jinchuan, China. First production was in June 2008. The concentrate produced in 2010 averaged 8.39% nickel. The Munali Mine was on care and maintenance from March to December 2009 until rampup problems were resolved and world nickel prices recovered.
[21]Includes "Russia, sulfide concentrate."
[22]Excludes "Australia, ores and concentrate."
[23]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	2009	2010	2011	2012	2013
Matte:					
Australia[4]	27,531	59,186	56,200 r	66,295	68,999
Botswana	27,905	25,127	28,800 e	17,948 r	22,848
Brazil[5]	8,518	14,308	13,703	14,345	11,641
Canada[6]	68,972	70,127	73,724	80,765	86,007 p
China[7]	--	1	--	--	--
Finland	735	10,381	16,088	12,915	8,662
Indonesia[8]	67,329	75,989	66,900	70,717	75,802
New Caledonia	13,902	13,917	13,780	13,417	13,279
Philippines	17,800	20,500	22,794	23,890	26,021
Russia[9]	100	85	65	1	--
South Africa	--	--	--	--	5,800
Zimbabwe[10]	1,608	3,105	3,519	3,787	7,500
Total, matte	234,000	293,000	296,000 r, e	304,000 r	327,000
Other:					
Cuba:[11]					
Sulfide precipitate	33,856	34,197	34,816	34,325	34,300 e
Ammoniacial liquor precipitate and unspecified[e]	2,400	2,400	2,400	2,300	2,300
Total, Cuba[e]	36,300	36,600	37,200	36,600	36,600
New Caledonia, nickel hydroxide cake	--	222	7,374 [12]	3,378	7,557
Papua New Guinea, mixed hydroxide product	--	--	--	5,283	11,369
Grand total, other[e]	36,300	36,800	44,600	45,300	55,500

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

[1]Includes data available through October 16, 2015. Data represent nickel content of matte and other intermediate materials produced.

[2]Estimated data, grand totals (other), Cuba totals, and matte totals 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: 2009—27,500 (revised); 2010—59,200 (revised); 2011—56,200 (revised); 2012—66,300 (revised); and 2013—70,000.

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

[6]Nickel content of reported exports. Matte from the smelter at Falconbridge typically assays 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: 2009—143,000; 2010—139,000; 2011—166,000; 2012—153,000 (revised); and 2013—160,000.

[8]Represents the nickel output of the Soroako smelter. The Soroako matte is shipped to Japan for further processing and contains 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 is estimated to be 25%.

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

[11]Corrected to remove byproduct cobalt.

[12]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 product[3]	2009	2010	2011	2012	2013
Australia:					
Metal	123,204	92,208 r	97,655	115,796	133,019
Unspecified[4]	8,006	9,390 r	12,558	12,963	8,500 p
Total	131,210	101,598 r	110,213	128,759	141,519
Austria, ferronickel and ferronickel molybdenum[e]	500 r	600	700	800	1,000
Brazil:[5]					
Ferronickel	9,427	8,465	16,750	31,342	34,501 p
Metal	16,598	19,111	20,521	21,437	19,823 p
Total	26,025	27,576	37,271	52,779	54,324
Burma, ferronickel	--	--	--	-- r	7,000 p
Canada, unspecified[6]	116,909	105,413	142,445	139,800	137,412
China:[e, 7]					
Ferronickel and high nickel pig iron	98,000	158,000	248,400 r	353,200 r	480,000
Metal	165,000	159,000	175,000	197,000 r	245,000
Chemicals and unspecified	8,000	8,500	8,900	9,000	9,000
Total	271,000	326,000	432,000 r	559,000 r	734,000
Colombia, ferronickel	51,802	49,443	37,817	51,595 r	49,320
Cuba, oxide sinter and oxides[8]	27,928 r	27,098 r	19,186 r	25,702 r	--
Dominican Republic, ferronickel	--	--	13,498	15,186	9,400
Finland:[9]					
Metal, electrolytic, including cathode and briquettes	41,848	41,317	43,840	39,374	44,498
Chemicals and unspecified, including powder, salts, solutions, and other	7,381 r	7,866	8,089 r	6,475 r	6,400 e
Total	49,229 r	49,183	51,929 r	45,849 r	50,900 e
France:					
Metal	11,996	10,799	11,697	11,273	11,200 e
Chemicals	1,959	2,080	2,039	1,927	2,000 e
Total[10]	13,955	12,879	13,736	13,200	13,200 e
Greece, ferronickel	8,269	13,956	18,527	18,632	16,826
India, ferronickel magnesium[e, 11]	88 [12]	96 [12]	107	114	200
Indonesia, ferronickel	12,550	18,688	19,690	18,373	18,249
Japan:					
Ferronickel	54,491	64,350	62,773	73,248	81,000 p
Metal	29,351	40,228	41,290	41,947	46,420
Oxide sinter	58,808	59,011	50,437	51,999 r, p	52,000 e
Chemicals	1,669	2,497	2,383	2,362	2,191
Total	144,319	166,086	156,883	169,556 r	182,000 e
Korea, Republic of:					
Ferronickel	21,609	20,512 r	19,011 r	20,858 r	25,376
Metal	(13)	(13)	(13)	(13)	(13)
Total	21,609	20,512 r	19,011 r	20,858 r	25,376
Kosovo, ferronickel	10,538	9,081	7,728	6,944 r	6,653
Macedonia, ferronickel	11,762 r	14,413	17,292	19,247	20,001
Madagascar, metal	--	--	--	5,695	25,148
Morocco, chemicals, including nickel sulfate	(14)	(14)	(14)	(14)	(14)
New Caledonia:					
Ferronickel	38,230	39,802	40,015	43,030	40,459
Nickel oxide sinter	--	--	--	2,353	7,911
Total	38,230	39,802	40,015	45,383	48,370
Norway, metal	88,577	92,185	92,427	91,687	91,000 e
Russia:					
Ferronickel					
High-nickel	15,565	16,799	16,899	9,782	--
Other[e, 15]	5,130	5,330 r	5,360 r	3,110 r	--
Total, ferronickel[e]	20,700 r	22,100 r	22,300 r	12,900 r	--
Metal	255,000 r	262,400 r	264,900 r	255,000 r	248,000
Chemicals	2,700	2,900 r	2,900 r	2,900 r	2,600 e
Total, Russia[e]	278,000 r	287,000 r	290,000 r	271,000 r	251,000

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 product[3]	2009	2010	2011	2012	2013
South Africa:					
Ferronickel, high-nickel	630	614	575	658	650 e
Metal	34,200	34,700	35,900	32,900 r	33,200
Chemicals[16]	5,044 r	5,353 r	5,564 r	5,093 r	5,100 e
Total	39,874 r	40,667 r	42,039 r	38,651 r	39,000 e
Taiwan, metal	100 r	400 r	400 r	400 r	400
Ukraine, ferronickel[17]	12,392	15,467	13,500 r	20,600 r	21,000
United Kingdom, metal[18]	38,700 r	31,650	37,400	34,300	34,000 e
Venezuela, ferronickel	10,400	11,700	13,300 r	8,100	8,100 e
Zimbabwe, metal, toll refined from imported nickel feed[19]	5,000 e	4,039	3,715	1,754 r	2,845
Grand total	1,400,000 r	1,470,000 r	1,630,000 r	1,800,000 r	1,990,000
Of which:					
Ferronickel, including ferronickel magnesium, ferronickel molybdenum, and high nickel pig iron	361,000 r	447,000 r	552,000 r	695,000 r	820,000
Metal	810,000 r	788,000 r	825,000 r	849,000 r	934,000
Oxide sinter	86,700	86,100	69,600 r	80,000 r	59,900
Chemicals, including nickel sulfate	11,400 r	12,800 r	12,900 r	12,300 r	11,900
Unspecified	140,000 r	131,000	172,000 r	168,000	161,000

[e]Estimated. [p]Preliminary. [r]Revised. -- 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 October 16, 2015.

[3]North Korea was believed 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, 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]Nickel contained in products of smelters and refineries in forms that are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. More information can be found in footnote 13.

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

[8]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. More information can be found in table 11.

[9]Most of the production was extracted from imported raw materials.

[10]Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.

[11]India's fiscal year ending March 31 of that year stated.

[12]Reported figure.

[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. Metal production was as follows, in metric tons: Republic of Korea: 2009—16,404; 2010—16,790; 2011—16,000; 2012—14,600 (revised estimate); and 2013—17,700 (estimated). Taiwan: 2009—11,148; 2010—12,200; 2011—11,706; 2012—13,500 (revised estimate); and 2013—14,300 (estimated).

[14]Nickel content of nickel sulfate is listed in table 10. 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]Tonnages include nickel contents of chemicals.

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

TABLE 13
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION BY YEAREND 2018[1]

Projected year of first production	Country (State/Province)	Project and company[1]	Resource grade (% nickel)	Estimated resources (thousand metric tons)[2]	Annual production capacity (metric tons of contained nickel)	Nickel product
2013	New Caledonia (Northern)	Koniambo (saprolite ores)/ North Plant Société Minière du Sud Pacifique S.A. (51%) and Xstrata Nickel (49%)	2.55 2.44 2.50	20,000 46,000 84,000	60,000	Ferronickel.
2013	Philippines (Surigao del Norte and Surigao del Sur)	Taganito mine and hydrometallurgical processing plant Mine ownership—Nickel Asia Corp. (65%), Pacific Metals Co., Ltd. (33.5%), and Sōjitsu Kabushiki-gaisha (SOJITZ) Corporation (15%) Hydrometallurgical processing plant ownership—Sumitomo Metal Mining Co., Ltd. (62.5%), Nickel Asia Corp. (22.5%), and Mitsui & Co., Ltd. (15%)	1.06 0.68	93,000 [3] 102 [3]	30,000	Nickel-cobalt sulfide.
2014[r]	Philippines (Agusan del Norte)	Agata (includes Bolobolo-Karihatag and Agata South) Mindoro Resources Ltd. and TVI Pacific Inc.	1.00 0.94 1.08 1.19 1.16 1.04	240 [4] 9,800 [4] 260 [4] 480 [5] 23,000 [5] 1,800 [5]	7,500 14,000	Phase 1, direct shipping ore. Phase 2, nickel-cobalt hydroxide.
2015	Indonesia (Tanjung Buli, East Halmahera, North Maluku)	East Halmahera (PT Feni Haltim) PT Antam (Persero) Tbk	2.17 2.20 1.58 1.40	4,700 [6] 550 [6] 5,000 500	40,000	Ferronickel.
2016	Indonesia (Southeast Sulawesi, North Konawe regency)	North Konawe nickel pig iron complex (Rotary kiln electric furnace smelter) Ibris Nickel Pte. Ltd. of Singapore and Yong-Xing Alloy Material Technology Co. Ltd. (Zhaoyang Industrial Park, Jiangsu, China)	XX	XX	48,000	Nickel pig iron briquettes (~8.0% nickel).
2016	Indonesia (South Halmahera regency, North Maluku)	Obi Island PT Megah Surya Pertiwi Rotary kiln-submerged arc electric furnace Harita Group (Indonesia), XinXing Qiyun Investment (China), Corsa Investments Pte. Ltd. (Singapore)	1.50	100,000	38,000	Ferronickel.
2017[r]	Philippines (Mindoro Oriental)	Mindoro I/Sablayan (Buraboy, Kisluyan, and Shabo areas) Aglubang Mining Corp. (local partner) and Intex Resources ASA	0.86 0.87	17,000 210,000	53,000	Metal.
2017[r]	Philippines (Zambales)	Acoje and Zambales—Stage 2 David M. Consunji, Inc. (DMCI) Holdings, Inc., ENK PLC (formerly European Nickel PLC),[8] and Montemina Resource Corp. (MRC)[9]	0.98 0.98	7,100 [7] 2,600 [7]	24,000	Nickel-cobalt hydroxide.
2017[r]	Turkey (Manisa)	Çaldağ Çaldağ Nikel Madencilik San. ve Tic. A.Ş., a subsidiary of OreMine Madencilik (OreMine Resources) San. ve Tic. A.Ş.	1.16	33,000	16,000	Do.
2018[r]	Australia (Queensland)	Lucky Break (Circular Laterite and Dingo Dam) Metallica Minerals Ltd. (50%) and Metals Finance Ltd. (50%)	0.82 0.82 0.75	590,000 48,000 490,000	730	Nickel carbonate. Cathode, later.
2018[r]	Australia (Queensland)	Marlborough (Coorumburra, Slopeaway, and Whereat)[10]—Stage 1 Gladstone Pacific Nickel Ltd.	0.99 0.91 0.70	12,000 43,000 70,000	63,000	Metal.

See footnotes at end of table.

TABLE 13—Continued

NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION BY YEAREND 2018[1]

Projected year of first production	Country (State/Province)	Project and company[1]	Resource grade (% nickel)	Estimated resources (thousand metric tons)[2]	Annual production capacity (metric tons of contained nickel)	Nickel product
2018[r]	Do.	SCONI [Scandium-Cobalt-Nickel] (formerly China North Industries Corporation [NORINCO]-Greenvale) [Bell Creek, Greenvale, Kokomo, Lucknow, and Minnamoolka deposits]	0.80 0.58 0.41	17,000 48,000 24,000	10,000	Metal.
		Metallica Minerals Ltd.				
2018[r]	Australia (Tasmania)	Barnes Hill, Mount Vulcan, and Scott's Hill	1.01	2,500	4,800	Cathode.
		Proto Resources & Investments Ltd.[11] and Metals Finance Ltd.	0.93	300		
2018[r]	Australia (Western Australia)	Mt. Thirsty (north-northwest of Norseman)	0.60 0.51	17,000 15,000	9,000	Nickel-cobalt hydroxide intermediate.
		Barra Resources Ltd. (50%) and Conico Ltd. (formerly Fission Energy Ltd.) [50%]				
2018[r]	Australia (junction of the Western Australian, South Australian, and Northern Territory borders)	Wingellina (high pressure acid leach project)	1.00 0.97	69,000 99,000	40,000	Nickel-cobalt hydroxide.
		Metals X Ltd. and Samsung C&T Corp.	0.97	16,000		
2018[r]	Indonesia (Maba, Southeast Sulawesi, North Konawe regency)	Mandiodo	2.12	3,200 [12]	20,000	Ferronickel.
		PT Antam (Persero) Tbk	2.10 1.49 1.50	2,000 [12] 18,300 [13] 13,000 [13]		
2018[r]	Indonesia (Southeast Sulawesi, North Konawe regency)	North Konawe	1.50	100,000	20,000	Do.
		Jilin Horoc NonFerrous Metal Group Co., Ltd. PT Billy Indonesia, and Government of Southeast Sulawesi				
2018[r]	Philippines (Romblon)	Romblon (Sibuyan Island—Bato, Binaya-an, and Taclobo	1.56	7,300	9,000	Direct shipping ore.
		Pelican Resources Ltd.				

[r]Revised. Do. Ditto. XX Not applicable.

[1]Company names reflect organizational structure as of October 19, 2015.

[2]Gross weight, dry. Rounded to no more than two significant digits and represent measured, indicated, and (or) inferred resources depending on the project. When two or more data sets are listed, the first resource data represent measured resources; the second, indicated resources; and the third, inferred resources, unless otherwise specified.

[3]Dry metric tons of limonite. Figures do not include saprolite resources.

[4]Limonite.

[5]Saprolite.

[6]Proved and probable reserves of nickel in saprolite, dry weight basis.

[7]Zambales—laterite.

[8]In April 2014, DMCI Holdings Inc. acquired full control of the British company, ENK PLC.

[9]Montemina Resource Corp. (MRC) has a 60% interest in the Zambales (laterite) part of the project.

[10]The Marlborough ores would be supplemented with ores from the mines of Société des Mines de la Tontouta and Société Miniere Georges Montagnat in New Caledonia.

[11]Proto Resources & Investments Ltd. was also evaluating the Waite Kauri North laterite deposit near Leonora in Western Australia.

[12]Measured and indicated resources of nickel in saprolite, dry tonnage.

[13]Measured and indicated resources of nickel in limonite, dry tonnage.

TABLE 14
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION BY YEAREND 2018

Projected year of first production	Country (State/Province)	Project and company[1]	Resource grade (% nickel)	Estimated resources (thousand metric tons)[2]	Annual production capacity (metric tons of contained nickel)	Nickel product
2013	Canada (Ontario)	Fraser Morgan	1.94	4,400	6,000	Ore.
		Glencore Canada Corp.	1.81	2,400		
			1.70	1,800		
2013	Canada (Quebec)	Nunavik (South Raglan) [Allammaq,	0.93	560	6,800	Concentrate.
		Expo, Ivakkak, Mequillon, Mesamax,	0.93	21,000		
		Puimajuq and TK deposits]	0.73	5,200		
		Canadian Royalties Ltd. (controlled by Jilin Jien Nickel Industry Co., Ltd.)[3]				
2013	Vietnam (Son La)	Ban Phuc	2.78 [4]	730	6,600	Do.
		Ban Phuc Nickel Mines LLP	2.60 [4]	960		
		Asian Mineral Resources Ltd. (90%) and	1.94 [4]	170		
		Son La Mechanical Engineering JSC	1.05 [5]	200		
		(10%)	1.23 [5]	700		
			1.14 [5]	400		
2014	Canada (Ontario)	Totten (plus new Clarabelle mill addition)	1.33	8,400	8,200	Do.
		Vale Canada				
2014	China (Gansu/ Beishan fold belt)	Heishan	0.60	23,000	5,000	Do.
		(Jinchuan Prefecture)	0.60	12,000		
		Jinchuan Group Co., Ltd.				
2014	China (Xinjiang Autonomous region/ East Tianshan)	Tula'ergen (aka Tulargen)	1.10	100,000	3,000	Do.
		(Qincheng Township, Hami Region)				
		Xinjiang Hami Hexin Mining Co., Ltd.				
		(joint venture of Xinjiang XinXin				
		Mining Industry Co., Ltd., and				
		Quinghai Industry Co., Ltd., and				
		Quinghai Western PreciousMetal				
		Co., Ltd.)				
2014	United States (Michigan)	Eagle	4.80	1,500	17,000	Do.
		Sold by Rio Tinto Group to Lundin	3.10	3,300		
		Mining Corp. in July 2013	1.00	49		
2015	Australia (Western Australia)	Cosmic Boy and Diggers[6]	1.46 [7]	2,100	7,000	Do.
		Western Areas Ltd.	2.40 [8]	380		
			1.00 [9]	10,000		
2015	Do.	Mt. Windarra and Cerberus	1.24	910	7,000	Do.
		Poseidon Nickel Ltd.	1.72	3,000		
			1.51 [10]	4,600		
2015	Canada (Ontario)	Onaping Depth	2.67	15,000	10,000	Do.
		Glencore Canada Corp.	3.60	1,200		
2015	Canada (Quebec)	Raglan-Qakimajurg	4.52	2,500	11,000	Do.
		Glencore Canada Corp.				
2015	United States (Minnesota)	NorthMet—100% controlled by Poly	0.08	210,000	7,100	Concentrate, initially.
		Met Mining, Inc.	0.07	590,000		Byproduct nickel-cobalt
		PolyMet Mining Corp. (partially owned	0.07	260,000		hydroxide, later.
		by Glencore AG)				
2016	Canada (Manitoba)	Minago	0.56	11,000	11,000	Concentrate.
		Victory Nickel Inc.	0.51	43,000		
			0.53	15,000		
2017	Australia (Western Australia)	New Morning/Daybreak	3.70 [4]	320	3,000	Ore.
		Western Areas NL	3.50 [4]	93		
			0.90 [5]	1,100		
2017	Do.	Radio Hill (bacterial heap leaching)	0.61	2,000	7,400	Nickel-cobalt sulfide
		Fox Resources Ltd.	0.42	2,000		precipitate and copper
						sulfide precipitate.
2017	Canada (Manitoba)	Makwa (formerly Maskwa)	0.61	7,200	3,600	Nickel sulfide concentrate.
		Mustang Minerals Corp.[11]	0.27	700		

See footnotes at end of table.

TABLE 14—Continued
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION BY YEAREND 2018

Projected year of first production	Country (State/Province)	Project and company[1]	Resource grade (% nickel)	Estimated resources (thousand metric tons)[2]	Annual production capacity (metric tons of contained nickel)	Nickel product
2017	Canada (Quebec)	Dumont Royal Nickel Corp. and Ressources Quebec Inc.	0.29 0.26 0.26	360,000 1,300,000 510,000	49,000	Sulfide concentrate of pentlandite and heazlewoodite plus concentrate of awaruite (Ni_3Fe).
2017	Canada (Sudbury, Ontario)	Copper Cliff Mine [merger and expansion] (formerly Copper Cliff Deep project) Vale Canada	1.15	130,000	NA	Ore.
2018	Botswana (Selebi-Phikwe region)	Dikoloti The Japan Oil, Gas and Metals National Corp. (81%) and Discovery Metals Ltd. (19%)	0.70	4,100	2,000	Nickel-cobalt sulfide concentrate.
2018	Canada (Ontario)	Eagle's Nest-McFaulds Lake Noront Resources Ltd. and Baosteel Resources International Co., Ltd.	2.08 1.50 1.10 0.31	5,400 5,600 9,000 1,600 [12]	15,000	Nickel sulfide concentrate.
2018	Do.	Kenbridge (open pit) Canadian Arrow Mines Ltd.	0.43 0.38	3,300 1,100	3,900	Ore.
2018	Canada (Yukon Territory)	Wellgreen Wellgreen Platinum Ltd. (formerly Prophecy Platinum Corp.)	0.26 0.26 0.24	92,000 240,000 850,000	14,000	Do.
2018	Finland (Oulu)	Kuhmo (Arola, Hietaharju, Peura-aho, Sika-aho, and Vaara) Altona Mining Ltd.[14] and Polar Mining Oy	0.55 [13]	6,000	3,000	Do.
2018	Russia (Amur)	Kun-Manie (Ikensoe, Maly Krumkon, and Vodorazdelny) Amur Minerals Corp.	0.61 0.48 0.54	3,700 48,000 17,000	16,000	Nickel-cobalt sulfide concentrate.
2018	Russia (Kola Peninsula)	Vuruchuaivench (10 kilometers southwest of Monchegorsk) MMC Norilsk Nickel-Kola MMC	0.23	17,500	NA	Metal.
2018	Russia (Taimyr Peninsula)	Maslovsky (Butter) Russian Platinum Co. (In late 2012 and 2013, ownership of the deposit was contested by MMC Norilsk Nickel—Polar Division)	0.33	730,000	18,000	Nickel sulfide concentrate.
2018	Tanzania (Lindi and Mtwara regions)	Nachingwea Regional Exploration Project, including Ntaka Hill Nickel Sulphide Project IMX Resources Ltd. and Minerals and Group (MMG) Exploration Holdings Ltd.[16]	0.58 0.66	20,000 [15] 36,000	25,000	Nickel sulfide concentrate.

Do. Ditto. NA Not available.

[1]Company names reflect organizational structure as of October 19, 2015. BHP Billiton Group is a dual listed company comprising BHP Billiton Ltd. and BHP Billiton Plc. Vale Nickel is a wholly owned subsidiary of Vale S.A.

[2]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits and represent measured, indicated, and (or) inferred resources depending on the project. When two or more data sets are listed, the first resource data represent measured resources; the second, indicated resources; and the third, inferred resources, unless otherwise specified.

[3]On March 22, 2012, Jilin Jien Nickel Industry Co., Ltd. purchased 95.62% of the outstanding shares of Goldbrook Ventures Inc. In May 2012, the company acquired the remaining shares (4.38%) of Goldbrook Ventures Inc. This acquisition gave Jilin Jien Nickel Industry Co., Ltd. 100% control of the Nunavik project.

[4]Massive sulfides.

[5]Disseminated sulfides.

[6]Includes Diggers Rocks, Diggers South, Purple Haze, and Seagull resources.

[7]Diggers areas—probable ore reserves.

[8]Cosmic Boy area—indicated resources.

[9]Diggers areas—indicated resources.

TABLE 14—Continued
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION BY YEAREND 2018

[10]Cerberus deposit.
[11]Mustang Minerals Corp. was also evaluating the potential of resources at the nearby Mayville property.
[12]Inferred resources of East zone.
[13]Kuhmo project area—total indicated and inferred resources.
[14]In July 2014, Altona Mining Ltd. sold all of its Finnish operations and most of its exploration assets in Finland to Boliden Mineral AB (Stockholm, Sweden).
[15]Measured and indicated resources.
[16]Continental Resources Ltd. and IMX Resources were in the process of merging to simplify development of the Ntaka Hill Nickel Project.

Sources: Australian Mines Atlas; Canadian Minerals Yearbook; company annual reports, presentations, and press releases; CRU International, Ltd.; and the International Nickel Study Group.