



# 2010 Minerals Yearbook

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NICKEL [ADVANCE RELEASE]

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# NICKEL

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The global recession of 2008–09 led to a dramatic decrease in world nickel mine production. At yearend 2010, several nickel mining companies were still struggling financially despite increased demand for the metal. World mine production bottomed out at 1.41 million metric tons (Mt) of contained nickel in 2009 but increased by almost 15% to 1.62 Mt in 2010 as the global economy improved and prices rose. The London Metal Exchange Ltd. (LME) monthly cash mean for nickel metal slowly recovered in the first half of 2010 and, despite the significant stock buildup in late 2009, ended 2010 at \$24,107 per metric ton. Substantial imports of nickel by Chinese consumers and speculative buying by hedge funds helped support the price recovery. Stocks of nickel metal in LME-sanctioned warehouses reached an alltime high of 165,870 metric tons (t) at the end of January 2010. At yearend 2010, LME stocks stood at 136,890 t, down by 14% from 158,424 t at yearend 2009.

The 2008–09 global recession affected almost every sector of the nickel market. Primary nickel usage, however, started to recover in early 2010 as demand for stainless steel rose. Stainless steel continued to account for more than 60% of global primary nickel consumption (Nickel Institute, 2011). In 2010, world production of stainless steel reached an alltime high of 31.1 Mt (International Stainless Steel Forum, 2012). China was the leading producer of austenitic stainless steel, accounting for about 38% of world output, and also the leading consumer of primary nickel. The European Union (EU) was the second ranked producer of stainless steel. In 2010, China produced more austenitic stainless steel than the United States and all of the countries in the European Union combined. The year-on-year growth rate for global stainless steel use declined by 5.7% (revised) in 2009, but then recovered to 23.2% in 2010. On a global basis, nonferrous alloys accounted for about 12% of primary nickel use, followed by electroplating and other surface finishing, with 11%. Another 10% was used to produce alloy steels other than stainless (International Nickel Study Group, 2011b, p. A1–A12; Vale S.A., 2011c, p. 3–7).

Reported nickel consumption (primary plus secondary) in the United States increased by 23% compared with that of 2009. U.S. apparent consumption of primary nickel was 113,000 t, or about 8% of world consumption. Stainless steel comprised only 46% of U.S. primary consumption, a relatively low percentage compared with similar economically developed countries. The low percentage for the United States was a reflection of the large number of specialty metal industries and a readily available supply of stainless steel scrap. U.S. industry reported melting an additional 105,000 t of nickel contained in scrap.

## Legislation and Government Programs

In conjunction with the American Recovery and Reinvestment Act of 2009 (Public Law 111–5), the U.S. Department of

Energy (DOE) funded a variety of programs designed to encourage more rapid development of renewable energy sources. Specific research and development projects included domestic manufacturing of advanced batteries; development of improved stationary and portable fuel cell power systems; development of commercial-scale biorefineries; improved design of molten-salt storage facilities at powerplants that concentrate solar energy; design and evaluation of parabolic troughs, dishes, and heliostats for solar power stations; and construction of demonstration facilities designed to recover and better utilize geothermal energy (U.S. Department of Energy, 2012). All of these expanding subsectors for generating power have the potential to be important users of nickel metal and (or) nickel-bearing alloys.

In the United States, domestic use of renewable energy increased by 21% from 2006 to 2010, and accounted for about 8% of U.S. energy consumption in 2010 (U.S. Energy Information Administration, 2011). In fiscal year 2010, Federal agencies implemented nearly 700 renewable energy initiatives. The Departments of Agriculture, Defense, Energy, and the Interior were responsible for almost 60% of these initiatives. The 679 identified initiatives supported 7 different renewable energy sources—bioenergy, geothermal, hydropower, ocean, solar, waste conversion, and wind (U.S. Government Accountability Office, 2012). Implementation of these technologies has the potential to increase the use of nickel-bearing steels and superalloys.

At the beginning of 2010, the U.S. Mint resumed production of the Jefferson nickel (25% nickel by weight) and the Roosevelt dime (8.33% nickel). The Mint had suspended production of the two coins in April 2009 in response to a slowing economy. The Mint produced a total of 490.6 million Jefferson nickels and 1,119.0 million Roosevelt dimes in 2010, up from 86.64 million nickels and 146.0 million dimes in 2009 (U.S. Mint, undated b).

Because of the popularity and budgetary benefits of both the 50 State Quarters™ Program and the Territorial Program, the U.S. Congress approved the Mint's request to launch a program in 2010 that would promote the Nation's parks and historical sites. As in 2009, minting was limited because of the sluggish economy. The U.S. Mint produced only 347.0 million commemorative quarters in 2010, down from 636.2 million in 2009. Each coin weighed 5.67 grams (g) and contained 8.33% nickel; thus 164 t of nickel was contained in the five commemorative quarters released in 2010 (U.S. Mint, undated a, b).

In 2010, the U.S. Mint produced 80.78 million Native American dollar coins and 321.4 million Presidential dollar coins. Each dollar coin weighed 8.1 g and contained 2.0% nickel, for a total use of 65 t of nickel (U.S. Mint, undated b, c).

## Mine Development and Production

**Michigan.**—Kennecott Eagle Minerals Co. continued to develop its Eagle copper-nickel mine near Big Bay. In January, the Michigan Department of Environmental Quality (MDEQ) formally approved the permits needed to begin construction of the \$300 million underground mine, after an administrative law judge ruled in favor of Kennecott at the conclusion of a series of strongly contested cases. Site preparation work began in April, with the mine scheduled to be completed by yearend 2012. Ore would be trucked from the mine to a renovated mill near Champion, where the copper-nickel sulfides would be concentrated. The concentrates would then be railed to Ontario, Canada, for smelting. Renovation of the Humboldt mill was expected to cost about \$100 million. In February, the Michigan Department of Natural Resources and Environment (the successor to MDEQ) issued the necessary permits to refurbish and operate the mill (Kennecott Eagle Minerals Co., 2010; 2012; Michigan Department of Environmental Quality, 2010; Pepin, 2010).

**Minnesota.**—PolyMet Mining Corp. (Vancouver, British Columbia, Canada) was preparing to mine the NorthMet deposit pending approval from the State of Minnesota. In late 2009, the Minnesota Department of Natural Resources released the revised draft environmental impact statement (EIS) for public comment. By yearend 2010, a supplemental draft EIS was in progress to better analyze the environmental impacts of the project and to more clearly demonstrate that the PolyMet project would fully comply with State and Federal environmental standards (PolyMet Mining Corp., 2010a).

The NorthMet deposit, a copper-nickel-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 0.29% copper and 0.08% nickel. Ore from the proposed open pit would be shipped to the reconditioned Cliffs Erie mill near Hoyt Lakes, MN, for processing through flotation. The concentrate would be processed at the Erie site in a new hydrometallurgical plant to produce copper cathode, nickel-cobalt hydroxide, and a precious-metals precipitate.

In November 2010, PolyMet agreed to sell \$30 million worth of common stock to Glencore International AG (Baar, Switzerland). The \$30 million would be used primarily to fund construction of the NorthMet Mine and to modify the Erie processing facility. Glencore made a similar equity investment of \$25 million in late 2009 (PolyMet Mining Corp., 2010b; 2011).

Duluth Metals Ltd. (Toronto, Ontario, Canada), Franconia Minerals Corp. (Spokane, WA), and Teck American Inc. (Spokane) 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, 2011). In July, Duluth Metals formed a joint venture with Antofagasta Plc (London, United Kingdom) to develop the Nokomis property. Antofagasta would own 40% of the new venture—Twin Metals Minnesota LLC—and would initially provide \$130 million to the project (Duluth Metals Ltd., 2011, p. 1–3, 7–11, 16–17; Newby and Moore, 2011).

**Byproduct Smelter and Refinery Production.**—The United States had no active nickel mines in 2010, although limited

quantities of byproduct nickel were recovered at some copper and precious metal refineries. In 2010, Stillwater Mining Co. shipped 525 t of nickel in crystalline sulfate, up from 388 t in 2009. Stillwater mined PGEs 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. In December, MMC Norilsk Nickel, Stillwater's majority shareholder, completed the sale of all of its common stock in the company to a broad spectrum of independent investors. The sale was valued at nearly \$1 billion and ended Norilsk's 7-year majority ownership in Stillwater (Stillwater Mining Co., 2011, p. 9, 16–18, 23–27, 52–54).

Freeport-McMoRan Copper & Gold Inc. (Phoenix, AZ) produced limited quantities of byproduct nickel carbonate at its El Paso, TX, copper refinery (Freeport-McMoRan Copper & Gold Inc., 2011, p. 26).

No ferronickel was produced in the United States in 2010 from either domestic or imported ores. Almost all U.S. ferronickel exports were either re-exports or material upgraded for special purposes. The steel industry accounted for virtually all the ferronickel consumed in 2010, with more than 97% used in stainless, heat-resistant, or specialty alloy steels.

**Secondary Production.**—At yearend 2009, Horsehead Holding Corp. (Pittsburgh, PA) acquired The International Metals Reclamation Co. (INMETCO) from Vale Inco Ltd. (Toronto, Canada) for \$34 million. INMETCO operated the only secondary smelter in North America dedicated to recycling both chromium and nickel from waste and scrap. The smelter at Ellwood City, PA, produced a 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 smelter also accepted filter cakes, plating solutions, sludges, and spent rechargeable batteries (Horsehead Holding Corp., 2010).

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 could treat nickel-molybdenum and cobalt-molybdenum hydrotreating catalysts that had been "poisoned" by nickel and vanadium tied up in porphyrins and other organometallic molecules of crude oil. Gulf Chemical first roasted and leached the catalysts to recover the molybdenum and vanadium. The nickel-and-alumina residue was then converted to a crude, but marketable nickel-cobalt alloy in a direct-current electric arc furnace (EAF) (Gulf Chemical & Metallurgical Corp., undated).

## Consumption

Apparent primary nickel consumption in the United States increased by 20% to 113,000 t in 2010 from 93,900 t in 2009. The estimated value of apparent primary nickel consumption was \$2.47 billion, up from \$1.38 billion in 2009. The sharp increase in the value of primary consumption resulted from a

49% increase in the LME cash price in addition to increased use in the aftermath of the recession. Apparent primary consumption plus reported secondary consumption totaled 218,000 t, up from 174,000 t (revised) in 2009 (table 1).

**Stainless Steel and Low-Alloy Steels.**—In 2010, stainless steel producers accounted for 46% of reported primary nickel consumption in the United States (table 4) and more than 60% of primary consumption in the world. Production of raw stainless steel and heat-resisting steel in the United States totaled 2.20 Mt in 2010, up by 36% from 1.62 Mt in 2009. Nickel-bearing grades accounted for 1.54 Mt, or 70% of total stainless steel production (American Iron and Steel Institute, 2011a, p. 72–73; b).

North American Stainless (NAS) in Ghent, KY, produced 899,000 t of stainless steel slabs—32% more than that of 2009. NAS was able to maintain its leading position in the U.S. flat products market during the global economic crisis (Acerinox, S.A., 2011, p. 24–25, 178–181).

In December, ThyssenKrupp Steel USA, LLC and ThyssenKrupp Stainless USA, LLC opened the first stage of a \$5.0 billion steelmaking and processing complex at Calvert, AL, which included a hot strip mill for processing 3 million metric tons per year (Mt/yr) of carbon steel slab from Brazil and can produce 4.1 Mt/yr of carbon steel end products. The second stage was to include a stainless steel meltshop capable of producing up to 1 Mt/yr of stainless steel slabs. The stainless slabs would be rolled at the new hot strip mill. The startup of the stainless steel meltshop was scheduled for December 2012. The meltshop would have a 160-t capacity EAF, a 180-t capacity argon oxygen decarburization (AOD) converter, and a 1,900-millimeter (72-inch) continuous caster. Of the \$5.0 billion, \$1.4 billion was being invested in the stainless melting and rolling part of the Calvert complex (ThyssenKrupp AG, 2010; ThyssenKrupp Steel USA, 2010).

**Superalloys and Related Nickel-Based Alloys.**—Of the primary nickel consumed in the United States, approximately 21% was used to make high-performance superalloys and related nickel-based alloys for the aerospace, electric power, and petrochemical industries. Flat or declining sales to manufacturers of jet aircraft engines and other sectors of the aerospace industry were offset by rising sales to the electrical energy and defense sectors.

Since 2007, U.S. aerospace sales have steadily increased in the military aircraft, space, and missile sectors of the industry. Civil aircraft sales, in contrast, fell from an interim high of \$42.9 billion in 2007 to \$36.6 billion in 2010 in terms of constant dollars. A number of factors accounted for the decline in civil sales, including a challenging global economy; the high and volatile price of jet fuel, which hurt airline revenues; new environmental regulations; and the reduced availability of aircraft financing. Lower demand for commercial aircraft in the United States and the European Union (EU) was partially offset by substantial exports of aircraft to Asia and the Middle East. Shipments of U.S.-manufactured civil jet transport decreased to 462 in 2010 from 481 (revised) in 2009. On a global basis, Airbus S.A.S. and The Boeing Co., the two leading manufacturers of large jet transport, delivered a total of 972 commercial aircraft in 2010, a slight decrease from the 979 in

2009 (Aerospace Industries Association, 2011, p. 3–7, 9–14; Airbus S.A.S., 2011; Nowlin, 2011).

In May, General Electric Aviation (an operating unit of General Electric Co.) signed a long-term sourcing agreement with Allegheny Technologies Inc. (ATI) to ensure an adequate supply of the nickel-based ATI 718Plus® superalloy, which has a wide variety of applications in jet engines and industrial gas turbines. The improved superalloy provides a nominal 55 °C (100 °F) temperature advantage over the traditional 718 alloy, enabling a jet engine of the same design to operate at a higher temperature. ATI has had a similar long-term sourcing agreement with Rolls-Royce plc (London, United Kingdom) for related alloys since 2009 (Allegheny Technologies Inc., 2010a, b; 2011, p. 5, 10, F3, F25–F26).

**Nickel Use in Industrial Gas Turbines.**—The use of natural gas for power generation has been increasing in recent years, spurring consumption of nickel for industrial gas turbines (IGT). The U.S. Energy Information Administration (EIA) has projected that the share of U.S. electric power generation from natural gas will rise to an average of 26.0% in 2015 from an average of 22.7% in 2010. ATI718Plus® could play an increasingly important role in the design and manufacturing of advanced turbines (Allegheny Technologies Inc., 2011, p. 15; U.S. Energy Information Administration, 2011, p. 2–4, 37–40, 78–80, 132; 2012).

Similar, high-performance, nickel-based superalloys were already being used in a variety of both gas and steam turbine components. Doncasters Group Ltd. (Burton-Upon-Trent, Staffordshire, United Kingdom) was a leading manufacturer of critical IGT components and assemblies. Doncasters had several subsidiaries in the United States that produced, cast, or machined nickel alloys. Certified Alloy Products Inc. (Long Beach, CA), for example, produced nickel and cobalt vacuum-refined superalloys for use in aerospace engine and IGT components. Doncasters Southern Tool (Oxford, AL) produced a variety of air and vacuum melt investment castings (Doncasters Group Ltd., 2008).

**Nickel Use in Geothermal Power Stations.**—Nickel-base superalloys and stainless steel play several important roles in geothermal operations. A geothermal powerplant is similar to a conventional steam turbine operation except that the steam is piped directly from a subterranean reservoir and must be cleaned of its suspended solids and dissolved salts before it can be used to spin the turbine. Piping made from a nickel-based superalloy or austenitic stainless steel is frequently used to minimize corrosion from salts in hot geothermal brines.

The U.S. geothermal energy industry continued to make headway in 2010 despite financing and permitting delays. In October, Energy Source LLC (El Centro, CA) began constructing a geothermal powerplant and chemical complex near Calipatria, on the southeastern edge of the Salton Sea in southern California. Phase I of the Hudson Ranch project was scheduled to come online in the spring of 2012. Construction of phase 2 would begin in early 2012. ThyssenKrupp VDM GmbH (Werdohl, Germany) was supplying 12-meter long sections of pipe fabricated from nickel alloy 625, a brine-resistant alloy strengthened by the addition of molybdenum and niobium (Richter, 2010; ThyssenKrupp AG, 2011; Wald, 2011).

In Nevada, Gradient Resources Inc. was preparing to launch the first phase of its Patua greenfield power project in Lyon County, east of Reno. Production well drilling started in 2010 (Chichon, 2012). DOE was evaluating an enhanced geothermal system (EGS)—Desert Peak—near Fernley in the Hot Springs Mountains of neighboring Churchill County. The DOE EGS stimulation well was adjacent to the existing geothermal power station operated by Ormat Technologies Inc. (Reno, NV) (U.S. Department of Energy, 2009, p. 1–14).

**Nickel-Based Batteries and Hybrid Electric Vehicles.**—U.S. demand for nickel in rechargeable batteries continued to increase. In 2010, most of the newer hybrid electric vehicles (HEVs) on U.S. highways used nickel-metal hydride (NiMH) batteries. 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 (Voelcker, 2010).

The battery market remained highly competitive and a variety of lithium ion (Li-ion) and lithium phosphate batteries began making inroads against the standard NiMH design. As an example, the Chevrolet Volt, an electric vehicle with extended range, has a Li-ion battery pack with 288 rectangular cells (General Motors Co., 2012). Some of the new proprietary lithium-ion batteries reportedly have four times the energy capacity of equivalent nickel-cadmium batteries and twice that of the newer NiMH products.

The General Electric Co. was converting a steam turbine assembly facility at Schenectady, NY, to a battery manufacturing facility. The \$100 million facility was expected to manufacture sodium-metal halide batteries containing nickel chloride as a key component. The advanced battery, designed for data centers and backup power, reportedly can store three times more energy than an equivalent conventional lead-acid battery (Rotman, 2012).

## Stocks

On January 1, 2010, stocks in LME warehouses worldwide totaled 158,424 t. LME stocks, which had been slowly building up from an alltime (end-of-month) low of 3,366 t in January 2007, peaked at 165,870 t on January 31, 2010. They then declined to 118,380 t on July 31, before rising to 136,890 t at yearend. Data collected by the International Nickel Study Group (INSG) indicated that, at yearend 2010, world nickel producers [excluding those in Austria, China, Macedonia, Kosovo (listed as Serbia by INSG), and the Ural region of Russia] had an additional 91,300 t of primary nickel stocks. About 70%, or 64,100 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 30% was class II material (products with a nickel content of less than 99%), which included ferronickel, oxide sinter, and East Asian utility nickel. All stocks in LME warehouses were class I (International Nickel Study Group, 2011b, p. A1–A2, A7–A8). In comparison, at yearend, U.S. consumer stocks of primary nickel totaled 11,200 t, 30% more than the 8,580 t (revised) held at yearend 2009 (tables 1 and 5).

## Prices

Nickel prices trended upward in 2010, driven by the global economic recovery. However, actions by hedge funds, institutional investors, and speculators caused sharp variations in pricing to be superimposed upon the general trend. The January 2010 average cash price for 99.8%-pure metal on the LME was \$18,435 per metric ton (\$8.362 per pound). A high of \$26,023 per ton (\$11.804 per pound) was reached in April. Nickel prices weakened slightly at midyear, declined to \$19,383 per ton (\$8.792 per pound) in June, but then slowly began to rise again. The monthly average for December was \$24,107 per ton (\$10.935 per pound), about 30% higher than that of January. The average annual LME price was \$21,804 per ton (\$9.890 per pound)—49% greater than the 2009 average.

## World Review

The world's leading producer of nickel ore was Norilsk (Russia), followed by Vale S.A. (Brazil and Canada) and the BHP Billiton Group (Australia and United Kingdom). PT Aneka Tambang Tbk. (Indonesia) was in fourth place, producing large tonnages of direct shipping ore for the Chinese nickel pig iron (NPI) industry. Other major producers were Eramet Group (France), Jinchuan Non-ferrous Metals Corp. (JNMC) (China), and Xstrata plc (Switzerland).

The global recession dampened acquisitions and mergers of nickel producers, with some exceptions. Altona Mining Ltd. (West Perth, Australia) took over management of the shuttered Hautalampi nickel-copper-cobalt mine along with the Kuhmo and Kylylahti copper-nickel projects—all in eastern Finland. Chinese companies continued to acquire mining interests throughout the world and signed offtake agreements or similar financial instruments with the owners of nickel mines in Australia, Canada, and the Philippines.

In 2010, world use of primary nickel was reported to be 1.46 Mt—an alltime high—and was 4% greater than the previous high of 1.40 Mt in 2006 (International Nickel Study Group, 2012, p. A–1 and A–5). A few nickel producers continued to operate at full capacity, but others cut back production and slowed development or postponed projects. Some producers were concerned about a possible double-dip recession and its effect on mid-term nickel prices. A prolonged labor dispute crippled Vale Nickel's mining and smelting operations in eastern Canada and contributed to lower output. Global demand continued to be buoyed by upward trending apparent consumption in China, which had risen to 575,000 t in 2010 from 66,800 t in 2000. The Chinese stainless steel industry continued to expand and used a record-high 425,000 t of primary nickel in 2010, a 25% increase from the amount consumed in 2009. The Chinese stainless steel industry overtook that of the EU in 2009 to become the leading consumer of primary nickel. The steel industry of the EU consumed 214,000 t of primary nickel in 2010, while the Japanese steel industry was in third place with 90,000 t (Eramet Group, 2012, p. 31–35).

Production of raw stainless steel (excluding production in China, the Commonwealth of Independent States, and Eastern

Europe) had increased at a compound annual growth rate of 5.1% since 1950. That rate included the recession period when production dropped from 20.8 Mt in 2007 to 16.1 Mt in 2009 (Vale S.A., 2011c, p. 4). According to the International Stainless Steel Forum (2012), stainless steel production for the entire world rose to 31.1 Mt in 2010 from 24.9 Mt in 2009 and 25.9 Mt in 2008.

**Australia.**—Australia was the fourth ranked nickel-producing country in the world. Seven companies in Western Australia reported producing salable nickel in 2010. One other company, plus two of the seven, trucked sulfide ore to BHP Billiton's concentrator at Kambalda for further processing [Department of Mines and Petroleum (Western Australia), 2011, p. 35–37].

**Laterite Operations.**—The Yabulu refinery of Queensland Nickel Pty. Ltd. processed laterite ores purchased from third party mines in Indonesia, New Caledonia, and the Philippines. In 2010, Yabulu produced about 29,400 t of nickel in compacts (a product similar to rondelles) averaging 98.5% nickel or greater (Queensland Nickel Pty. Ltd., 2011).

In February, First Quantum Minerals Ltd. purchased the idled Ravensthorpe complex in Western Australia from BHP Billiton. First Quantum thought that if \$150 million worth of modifications were made to the front end of the complex, the plant would be capable of producing between 28,000 and 39,000 t/yr of nickel metal. Recommissioning was scheduled for late 2011 (First Quantum Minerals Ltd., 2010a; b, p. 9–12).

The Murrin Murrin joint venture near Leonora, Western Australia, used sulfuric acid to leach nickel and cobalt from lateritic ores in high temperature, high-pressure autoclaves. The laterite mining and processing operation produced 28,378 t of nickel, down by 14% from the 32,977 t produced in 2009. Murrin Murrin was jointly owned by Minara Resources Ltd. (60% interest) and Glenmurrin Pty. Ltd. (a subsidiary of Glencore) (40%). Nickel production declined in 2010, owing to a pipeline failure in the autoclave circuit in May and a triennial statutory shutdown in October. In 2010, Murrin Murrin mined 3.2 Mt (dry) of ore grading 1.29% nickel and 0.093% cobalt. In September, the company began developing the Murrin Murrin East orebody. In late 2010, Minara also added a sixth reduction autoclave and a second flash vessel to the refinery's nickel circuit to make the operation more flexible (Minara Resources Ltd., 2011, p. 2, 4, 6, 16, 19).

**Sulfide Operations.**—*Tasmania.*—The Avebury Mine [Minmetals Australia Pty. Ltd. (Melbourne, Victoria)] remained on care-and-maintenance status throughout 2010. Minmetals acquired Avebury from OZ Minerals Ltd. as part of a \$1.4 billion buyout in late 2009.

*Western Australia.*—In 2010, BHP Billiton's Nickel West produced 43,600 t of metal briquettes and powder at Kwinana from matte made at Kalgoorlie. Kwinana also produced several intermediate products, including cobalt-nickel sulfide, copper sulfide, and ammonium sulfate. The Kalgoorlie smelter produced about 61,700 t of nickel in finished matte for export. The matte typically contained 68% nickel. About one-third of the concentrate came from the Mount Keith Mine in the Northern Goldfields region. The remaining two-thirds came from Leinster and third party mines at Kambalda.

Nickel West continued to expand its Mount Keith operation and was reevaluating the undeveloped Yakabindie deposit, 25 kilometers (km) south of Mount Keith. In September 2009, contractors began constructing a magnesium oxide flotation circuit at Mount Keith designed to separate the talc from the pentlandite concentrate, producing a marketable coproduct. About 25% of the remaining nickel ore reserves at Mount Keith contain excessive levels of talc. The talc circuit was scheduled to come onstream in 2012. The Mount Keith operation also was concentrating high-grade ore from the company's new Cliffs underground mine, 12 km to the south (BHP Billiton, 2011, p. 40–41, 57, 87).

In 2009, Norilsk Nickel International temporarily suspended production at all of its mining operations in Western Australia owing to the unfavorable global economic situation. The Lake Johnston sulfide flotation plant and all five of Norilsk's mines in the Leinster-Kalgoorlie region were still on care-and-maintenance status at the end of 2010. The idled mines—all underground—included the Black Swan-Silver Swan complex, the Emily Ann, the Maggie Hays, and Waterloo (OJSC MMC Norilsk Nickel, 2011, p. 52–55, 62).

Western Areas NL mined 266,000 t of sulfide ore grading 3.9% nickel and containing 10,479 t of recoverable nickel at its Flying Fox underground mine at Forrestania in fiscal year ending June 30, 2010. In June, Western Areas commissioned the Tim King open pit at its new Spotted Quoll Mine, also in the Forrestania District. Ore from the Tim King was grading 6.3% nickel. The first sulfide concentrate from the company's newly upgraded Cosmic Boy mill was shipped to the Jinchuan Non-ferrous Metals Group in China for downstream processing as part of an offtake agreement. Development of the underground portion of the Spotted Quoll ore complex was scheduled to begin in March 2011. The new underground workings would be reached from a decline being constructed in the pit wall of the Tim King [Department of Mines and Petroleum (Western Australia), 2011, p. 35–36; Western Areas NL, 2010, p. 3–14].

**Brazil.**—Four companies mined nickel ore in Brazil in 2010—Anglo American Brasil Ltda., Cia. de Nickel do Brasil, Grupo Votorantim, and Mirabela Nickel Ltd. Two major mining and metallurgical processing complexes were essentially completed—the Barro Alto ferronickel smelter and refinery in Goias State (Anglo American plc) and the Onça Puma mining and ferronickel complex in Para State (Vale Nickel). In March, however, Votorantim Metais Niquel S.A. (a subsidiary of Grupo Votorantim) reportedly suspended work on its new Niquelandia ferronickel smelter in Goias State.

Votorantim Metais 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 electrolytic nickel and 1,420 t/yr of electrolytic cobalt. The Sao Miguel Paulista refinery used intermediate nickel carbonate from the company's operation in Niquelandia for feed. The electrolytic nickel was 99.9% pure and was registered on the LME. The sulfide smelter of Votorantim Metais at Fortaleza de Minas, Minas Gerais State, produced 14,308 t of nickel in matte in 2010, primarily for export to Finland, up from

8,518 t in 2009. The matte typically assays 50% to 55% nickel, 7% to 12% copper, and 0.14% to 1% cobalt (Da Silva, 2012; International Nickel Study Group, 2011b, p. B–10; Votorantim Metais, 2008).

In October, Vale Nickel began ramping up production at its new Onça Puma complex in the Ourilandia do Norte District, Para State. The Onça and Puma Mines have a combined 82.7 Mt of saprolitic reserves averaging 1.73% nickel. Ores from the two open pits were being blended in coal-fired rotary kilns and then charged into electric furnaces to produce ferronickel. Onça Puma was expected to reach its full production capacity of 53,000 t/yr of nickel-in-ferronickel in late 2012. The entire project was expected to cost \$2.84 billion (Hatch Ltd., 2011, p. 22; Vale S.A., 2011b).

In December 2010, Anglo American plc began commissioning its Barro Alto smelter in Goiás State and poured the first molten ferronickel in March 2011. When fully operational in late 2012, Barro Alto would be capable of producing 41,000 t/yr of nickel-in-ferronickel. Capital expenditures for Barro Alto totaled \$1.9 billion. Saprolitic ore from the adjoining Barro Alto Mine was already being processed at Anglo's existing Codemin ferronickel plant, 170 km away in Niquelandia. In 2010, the Codemin plant produced 8,465 t of nickel-in-ferronickel. The Codemin open pit had 7.7 Mt of proven and probable lateritic reserves averaging 1.28% nickel. The Barro Alto open pit had 47.5 Mt of proven and probable lateritic reserves grading 1.68% nickel. The ferronickel plant had two 185-meter-long rotary kilns for calcining the raw ore and two 83-megawatt (MW) EAFs for final smelting (Anglo American plc, 2011a; 2011b, p. 59–68).

In August 2009, Mirabela Nickel Ltd. (Perth, Australia) began mining nickel and copper sulfides at its Santa Rita project near Ipiau, Bahia State. The crushing, grinding, and concentrating complex was commissioned in October 2009. After ramp up was completed in 2010, Santa Rita had the capacity to produce 27,000 t/yr of nickel in sulfide concentrate. Mirabela was shipping 50% of the concentrate produced at Santa Rita to Norilsk Nickel's Harjavalta smelter in Finland. The remaining 50% was trucked 1,350 km to Votorantim's Fortaleza smelter in Minas Gerais. Mirabela sold 9,956 t of nickel in concentrate to Votorantim Metais in 2010 as part of its offtake agreement. Santa Rita reportedly had 16.7 Mt of proven reserves averaging 0.57% nickel and 143 Mt of probable reserves grading 0.52% nickel (Mirabela Nickel Ltd., 2011, p. 7–10).

**Canada.**—Four Provinces had active nickel mines in 2010—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.

**British Columbia.**—In 2007, exploration companies began discovering disseminated awaruite, a naturally occurring nickel-iron alloy, in the ultramafic complexes of northern British Columbia. Nickel has traditionally been extracted from three ore types—sulfide ores containing pentlandite and chalcopyrite; lateritic ores rich in limonite; or lateritic ores rich in saprolitic mineralization such as garnierite. First Point Minerals Corp. (Vancouver, British Columbia), however, decided to evaluate the awaruite potential of the Decar, Klow, Wale, and four other properties in the province. The Decar project, on the west

bank of the Stuart River, is a joint venture with Cliffs Natural Resources Inc. (Cleveland, OH). Composite samples from the Decar property averaged 0.14% nickel in alloy. Preliminary metallurgy work on samples from the Decar property produced a ferronickel concentrate grading 2.6% nickel, 2.2% chromite, and 52% iron as magnetite. About 80% of the nickel iron-alloy was recoverable (First Point Minerals Corp., 2011).

**Manitoba.**—Vale Nickel's operations at Thompson produced 29,800 t of refined nickel in 2010 from ores extracted from the Birchtree and Thompson Mines. The Thompson Mine produced 1.33 Mt of ore grading 1.83% nickel; the Birchtree, 832,000 t grading 1.41% nickel (Vale S.A., 2011a, p. 38–39).

In November 2009, Crowflight Minerals Inc. (renamed CaNickel Mining Ltd. in 2011) suspended mining and milling for 3 months at its new Bucko Lake Mine near Wabowden. The action was taken so that key improvements and upgrades could be made to the underground part of the operation. The company resumed milling and shipments of concentrate in March 2010, but suspended operations in October until spring 2011 (CaNickel Mining Ltd., 2012, p. 4–9).

**Newfoundland and Labrador.**—The Ovoid Mine at Vale Nickel's Voisey's Bay operation extracted 1,510,000 t of ore grading 3.20% nickel and 2.44% copper. The mined tonnage yielded 42,300 t of finished nickel, up from 39,700 t in 2009, but down from a record 77,500 t in 2008. A prolonged labor dispute that began in August 2009 and continued until January 2011 was responsible for the substantial drop in production of finished nickel. Vale has been constructing a hydrometallurgical processing plant at Long Harbour, Newfoundland, since April 2009. The Long Harbour plant was scheduled to begin operation in 2013 using concentrates from Voisey's Bay as feed. In 2010, Vale Nickel shipped the high-grade nickel concentrate produced at Voisey's Bay to Sudbury and Thompson for smelting and downstream processing (Vale S.A., 2011a, p. 38–39; 2012).

**Ontario.**—Sudbury has been the leading nickel-producing district in Canada since the discovery of the first ore body in 1883. Vale Inco's Ontario Division operated at well below capacity for most of 2010, owing to a prolonged strike that began in July 2009 and lasted until July 2010. The strike was the longest in the history of the Sudbury-Port Colborne operation (Kosich, 2010). As a result, the division produced only 22,400 t of finished nickel in 2010 from its own ores, down from 43,600 t in 2009 and 85,300 t in 2008. The division had seven mines operating in 2010. Part of the refined nickel was recovered from intermediate nickel oxide at the division's Clydach refinery in the United Kingdom. Despite the ongoing strike, Vale Inco continued to develop its new \$450 million Totten Mine. The partially completed mine produced 16,000 t of ore grading 2.54% copper and 1.74% nickel in 2010 (Vale S.A., 2011a, p. 38–39).

Xstrata, Sudbury's other principal producer, mined 1,216,000 t of ore with an average grade of 1.40% nickel and 2.81% copper (Xstrata plc, 2011b, p. 7–8). Xstrata's smelter at Falconbridge produced 73,667 t of nickel in matte, which was shipped to the company's Nikkelverk operations in Norway for refining. On April 1, Xstrata officially commissioned its new Nickel Rim South Mine. The main shaft is about 9 km northeast of Xstrata's smelter at Falconbridge. The Nickel Rim South ore

body, which was discovered in 2001 and cost \$809 million to develop, reached its nameplate capacity of 1.25 Mt/yr of ore in October, 6 months ahead of schedule (Xstrata plc, 2011a, p. 10, 34–35, 83, 98).

In May, FNX Mining Co. Inc. merged with Quadra Mining Ltd. to form Quadra FNX Mining Ltd. The new company operated the Levack/Morrison, McCreedy West, and Podolsky Mines—within 35 km of Sudbury—and retained the mineral rights to the Kirkwood and Victoria properties (Quadra FNX Mining Ltd., 2011, p. 7–8, 17–32).

In June 2009, Xstrata suspended mining indefinitely at its Montcalm Mine near Timmins after a geotechnical review revealed that subterranean rock failure and subsequent movements had structurally damaged the mine. The Montcalm Mine was idle in 2010 owing to safety concerns and the need to fully assess the situation (Xstrata plc, 2009; 2011b, p. 8).

In 2010, Noront Resources Ltd. (Toronto) discovered additional nickel-copper-PGE mineralization at its Eagle's Nest deposit in the McFaulds Lake District. The district is located in the James Bay Lowlands, north of the Albany River. The district is the site of two massive chromite zones and a variety of nonferrous metal targets in and around a large ultramafic intrusion—the Ring of Fire (53° N latitude, 86° W longitude). At yearend 2010, the Eagle's Nest had 11.1 Mt of proven and probable reserves averaging 1.68% nickel and 0.87% copper. The reserve figures exclude additional nickel-copper resources at Noront's recent "Eagle Two" and "AT-12" discoveries. Noront was planning to complete a full feasibility study by yearend 2012. The sulfide concentrate would be slurried and pumped through a pipeline from the underground mine to Webeque Junction (Ontario Prospector, The, 2010; Schwartz, 2010; Noront Resources Ltd., 2011a, p. 1, 4–7, 14–19, b).

**Quebec.**—Xstrata's Raglan Mine in northern Quebec produced 28,237 t of nickel in concentrate, which was 4% less than the 29,262 t recovered in 2009 (Xstrata plc, 2011b, p. 8).

**China.**—China produced 171,300 t of electrolytic nickel in 2010, up slightly from 170,600 t in 2009. Electrolytic nickel from Jinchuan Non-ferrous Metals Corp. (JNMC) accounted for 129,800 t, or 76% of the national total. JNMC operated the Yongchang mining complex at Jinchang in Gansu Province. Jilin Jien Nickel Industry Co., Ltd. produced about 7,800 t of nickel in salts in 2010, up from 7,200 t in 2009. Jilin Jien had two operations in Jilin Province plus the Siziwngqi Mine in Inner Mongolia. At least five other companies produced primary nickel in China during 2010 (Copper & Nickel Monthly, 2011, p. 14–15).

Chinese demand for primary forms of nickel continued to escalate and was estimated to have reached 575,000 t in 2010, which was 22% greater than that of 2009. The Chinese stainless steel industry accounted for 74% of the country's primary nickel consumption. China was the world's leading stainless-steel-producing country in 2010, with a crude stainless steel output of 12.0 Mt, 26% greater than the 9.55 Mt in 2009. Chinese production of stainless steel has been increasing at an average annual rate of 33% since 2000. Five companies—the Baosteel Group, Henan Tsingshan Jinhui Stainless Steel Industry Co., Ltd., Lianzhong Iron and Steel Co. (LISCO), Taiyuan Iron & Steel (Group) Co., Ltd. (TISCO), and Zhangjiagang Pohang

Stainless Steel Co. Ltd. (ZPSS)—accounted for about 68% of the country's stainless steel meltshop production (Vale S.A., 2011c, p. 4, 16, A–37; Eramet Group, 2012, p. 39).

Since 2001, China had consumed more stainless steel annually than any other country. In 2010, China consumed 9.47 Mt of stainless steel, about 37% of the world total and a tonnage larger than the total consumption of Japan, the United States, and Western Europe combined. Chinese imports of stainless steel had been declining since 2006 and decreased to 1.05 Mt in 2010, the lowest level in more than a decade. Exports, in contrast, exceeded imports for the first time since data were made public in 1998 and rose to a record high of 1.43 Mt in 2010 (Vale S.A., 2011c, p. 6–7, 12, 16, A37–A38).

China has a large electroplating industry and a number of rechargeable battery manufacturers that use nickel. China's plating industry accounted for about 12% of the country's primary nickel demand in 2010, while battery manufacturers consumed another 5%. The alloying and foundry sector accounted for the bulk of the remaining 9% (Xu Aidong, 2011, p. 7; Eramet Group, 2012, p. 39).

Since 2005, China's stainless steel producers have been using relatively inexpensive nickeliferous pig iron (NPI) as a substitute for ferronickel and scrap. In 2010, there were more than 200 NPI operations in the country. The two most common grades contained either 4% to 6% nickel or 10% to 15% nickel. The market price for NPI was very close to production costs. At yearend, Tsingshan Holding Group Co., Ltd. commissioned a new NPI operation utilizing EAF technology in Ningde, Fujian Province (Copper & Nickel Monthly, 2011, p. 23–24).

**Indonesia.**—PT Aneka Tambang Tbk. (Antam) increased production of both limonite and saprolite as sales to NPI producers in China and other overseas customers began to improve. The state-owned company mined 6.99 Mt (wet) of various laterite ores, approaching the alltime high of 7.11 Mt reached in 2007. About 83% of the production was direct shipping ore for export—primarily to Australia, China, Eastern Europe, and Japan. Antam produced 18,688 t of nickel in ferronickel, up 49% from 12,550 t in 2009. Antam's three smelters at Pomalaa had a combined capacity of 26,000 t/yr of nickel in ferronickel (in the form of ingot and shot averaging 19% to 21% nickel). The smelting part of the operation required 70 to 85 wet tons of ore to produce 1 ton of nickel contained in ferronickel (PT Aneka Tambang Tbk., 2011, p. 25, 53–55, 76–77, 80).

PT Vale Indonesia Tbk. (formerly PT Inco) mined 4.18 Mt of ore averaging 2.00% nickel from its Sorowako concessions on Sulawesi. The production figure represents the amount of product delivered to the company's smelter from its adjoining dryer kilns. The smelter produced 78,400 t of nickel in matte for export to Japan, up from 68,800 t in 2009. Vale has a 59% interest in the Indonesian company (Vale S.A., 2011a, p. 38–39).

**Madagascar.**—The Ambatovy project was in the final stages of construction, with commissioning scheduled for mid-2012. In July, crews began mining and stockpiling ore. At yearend, all of the engineering work was finished and construction was 80% complete. The Ambatovy project was being built around the Sherritt hydrometallurgical process for recovering nickel and cobalt from lateritic ores. The Ambatovy ore was to be

piped 220 km from the mining area to the processing plant as a water-based slurry. At the processing plant, the ore would be leached with hot sulfuric acid in autoclaves to produce a mixed sulfide intermediate of nickel and cobalt. The mixed sulfide intermediate would then be dissolved to produce a concentrated solution of nickel and cobalt. The facilities housing the final stage of the operation, in which the cobalt and nickel would be separated by solvent extraction, still needed to be completed (Daigle and others, 2011, p. 152–162; Sherritt International Corp., 2011, p. 2–3, 30, 37).

**New Caledonia.**—Société Le Nickel (a subsidiary of Eramet) produced 39,802 t of nickel in ferronickel at its Doniambo smelter. The smelter also produced 13,917 t of nickel in matte, which was shipped to Eramet's Sandouville refinery in France for conversion into LME-grade metal and chemicals (Eramet Group, 2011, p. 22–25; International Nickel Study Group, 2011a; b).

At yearend 2010, Vale Nouvelle-Calédonie SAS (VNC, formerly named Goro Nickel SAS) was still conducting performance tests at its new Grand Sud hydrometallurgical plant. Performance testing of the autoclaves began in February, but commissioning of downstream operations was delayed when two solvent extraction columns failed in April. The solvent extraction columns were a critical part of the complex's refining circuit. The mixed hydroxide precipitate circuit in the upstream part of the operation, however, was able to produce 221 t of nickel in a hydroxide cake suitable for further processing at Yabulu. The \$4.3 billion mining and processing complex was expected to have a production capacity of 60,000 t/yr of nickel in intermediate product (International Nickel Study Group, 2011b; Vale S.A., 2011a, p. 34–37).

Société Minière du Sud Pacifique and its joint-venture partner, Xstrata, have been developing the Koniambo laterite deposit in the Northern Province since February 2007. Nickel was to be extracted from the saprolite and converted to ferronickel using an improved version of the pyrometallurgical process employed at Xstrata's Falcondo smelting and refining complex in the Dominican Republic. By the beginning of 2010, the bulk of the site infrastructure was completed for the \$3.85 billion project. Construction of the smelter and 270 MW powerplant was essentially finished by January 2011. The two plants were assembled onsite from an array of modules built in China and then transported by ship to the new port of Vavouto. Commissioning was scheduled for the second half of 2012. When fully operational, the Koniambo smelter should be capable of producing 60,000 t/yr of nickel in ferronickel shot, which was expected to average 35% nickel, 63% iron, and 0.9% cobalt (Usmar, 2011).

**Russia.**—About 79% of Norilsk's sales of marketable nickel came from its Russian operations. The other 21% was generated by the company's holdings in Botswana, Finland, and South Africa. Norilsk's Australian subsidiary was on care-and-maintenance status for 2010. Norilsk's operations on the Kola and Taimyr Peninsulas had a combined output of 235,518 t of nickel metal—about 90% of Russia's primary nickel output for the year. Norilsk's two Arctic subsidiaries exported almost all of their nickel production; only about 10,000 t, or less than 5%,

was sold to Russian consumers (OJSC MMC Norilsk Nickel, 2011, p. 57–68, 181).

OAo Mechel (Moscow) owned and operated the Southern Urals ferronickel smelter in Orenburg Oblast and the two laterite mines—Buruktal and Sakahara—that supplied the operation. Mechel produced 16,799 t of nickel in low-iron ferronickel in 2010. An estimated 12,600 t was shipped to the ports of Kaliningrad and St. Petersburg for export to the EU. The remainder was used to make stainless steel at Mechel's stainless steel plant at Chelyabinsk (OAo Mechel, 2011, p. 102–109).

**Turkey.**—In 2009, Meta Nikel Kobalt A.Ş began mining ore at its Yunusemre open pit operation in Eskisehir Province. The company also applied for the necessary permits needed to construct and operate an ore processing plant near its idled Gordes Mine in Manisa Province. Meta Nikel Kobalt has reportedly completed the environmental impact assessment required by Turkish law in addition to a feasibility study of the plant. Between 2003 and 2008, Meta Nikel Kobalt mined 230,000 t of nickel ore from the Gordes Mine. About 150,000 t of ore was exported, while the remaining 80,000 t was stockpiled. Meta Nikel Kobalt is a subsidiary of Meta Madencilik Ltd. Şti. (Mobbs, 2012, p. 56.3, 56.5).

In December 2010, ENK PLC (formerly European Nickel PLC) placed its innovative Caldag heap-leaching project on care-and-maintenance status. The company had been evaluating the laterite deposit, 15 km north of Turgutlu, since 2002. In 2004, the Government of Turkey issued an environmental license to European Nickel, allowing the company to begin heap leaching on a trial basis. In February 2009, the Government issued the key forestry permit required to begin construction and full development. In June 2010, however, the Turkish parliament passed a new mining law that required EKN to apply for an updated forestry permit. The new permit was never issued, forcing EKN to reassess the viability of the Caldag project. The project was to have produced 21,000 t/yr of nickel in a mixture of nickel and cobalt hydroxide. Also in June, European Nickel merged with Rusina Mining NL (West Perth, Australia) and began focusing its resources on a similar heap-leaching project in the Philippines (ENK PLC, 2010; Olchondra, 2010).

## Outlook

U.S. nickel consumers will probably be dependent on foreign sources of refined metal and ferronickel for at least the next 25 years. The ongoing expansion of nickel laterite mining operations in Brazil, Indonesia, New Caledonia, and other tropical countries will help meet the increasing demand for nickel worldwide. The nickel output from both 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 near-term rise in global demand projected after 2014. Long-range forecasts of increasing usage in Asia have encouraged parastatal companies in China to fund the development of greenfield laterite mines in Burma, Papua New Guinea, and Turkey. European and North American companies were seriously considering funding large-scale laterite projects in Cameroon, Guatemala, the Philippines, and Tanzania.

Exploration companies have begun 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. Developments of high-grade sulfide deposits, however, are becoming less frequent because the deposits are harder to find and located farther from shipping routes. These new projects are more costly to finance owing to their remoteness, stricter environmental regulations, and increased technical complexity. Advances in extraction technology may offer a solution. 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 bioheapleaching.

Concerns about global warming and associated climate changes have encouraged research, development, and construction in the renewable energy sector. In recent years, Congress and several Executive Departments have supported a variety of initiatives designed to encourage increased development and expanded use of renewable energy in the United States. This support was being driven in part by concerns about continued U.S. reliance on imported petroleum products, rising energy costs worldwide, and the possible contribution of fossil fuel combustion products to global climate change. The retrofitting of coal-fired powerplants to reduce carbon dioxide emissions remains a national issue (Deutch and Moniz, 2009). Many older coal-fired powerplants in the United States 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 will replace some of these coal-based facilities.

Global demand for electricity, however, continues to increase. To meet demand, the power industry will have to build many more generating stations—stations that either operate on renewable energy (geothermal, solar, or wind) or are designed to better utilize uranium or thorium (safer, fourth generation nuclear reactors). Development of advanced coal-fired plants, especially ones that operate with ultra-supercritical steam, would also help. All of this construction would require large tonnages of nickel-bearing stainless steel and superalloys (Kirsch, 2009; Wong and Coates, 2010).

Demand for nickel in the transportation sector is also expected to increase. Chinese, European and North American usage of nickel- and cobalt-base superalloys was expected to escalate between 2013 and 2017, largely because of increasing demand for new jet aircraft that have more-fuel-efficient engines. The Boeing Co. and Airbus S.A.S. both have a large backlog of jet-aircraft orders. Boeing forecasts an average growth rate of 5% to 6% per year for global passenger and cargo air traffic between 2011 and 2031. An estimated 33,500 new airplanes would have to be built during the 20-year period to meet demand. Some energy analysts have predicted that world crude oil production may peak a decade earlier than predicted—perhaps as soon as 2014. Significantly higher gasoline prices could encourage the replacement of conventional automobile steel frames with lighter ones fabricated from stronger stainless steel. The burgeoning development of renewable energy sources was expected to accelerate research on cost-effective, more

advanced batteries, especially for automobiles and remote power stations (Nashawi, Malallah, and Al-Bisharah, 2010; Boeing Co., The, 2012, p. 22–26).

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TABLE 2  
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES,  
BY KIND OF SCRAP AND FORM OF RECOVERY<sup>1</sup>

(Metric tons of contained nickel)

	2009	2010
Kind of scrap:		
Aluminum-base <sup>2</sup>	1,620 <sup>r</sup>	1,690
Copper-base	1,160	1,280
Ferrous-base <sup>3</sup>	72,100 <sup>r</sup>	95,900
Nickel-base	4,950 <sup>r</sup>	5,680
Total	79,900 <sup>r</sup>	105,000
Form of recovery:		
Aluminum-base alloys	1,620 <sup>r</sup>	1,690
Copper-base alloys	1,890 <sup>r</sup>	2,080
Ferrous alloys	72,200 <sup>r</sup>	96,900
Nickel-base alloys	4,180 <sup>r</sup>	3,920
Total	79,900 <sup>r</sup>	105,000

<sup>r</sup>Revised.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Primarily borings and turnings of wrought alloys, such as 2218, 2618, 4032, and 8280, or special casting alloys, such as 203.0.

<sup>3</sup>Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

TABLE 3  
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM<sup>1</sup>

(Metric tons of contained nickel)

Form	2009	2010
Primary:		
Metal	72,800 <sup>r</sup>	83,600
Ferronickel	9,210 <sup>r</sup>	11,400
Oxide and oxide sinter <sup>2</sup>	116 <sup>r</sup>	214
Chemicals	864	1,270
Other	842 <sup>r</sup>	1,020
Total	83,800 <sup>r</sup>	97,500
Secondary, scrap <sup>3</sup>	79,900 <sup>r</sup>	105,000
Grand total	164,000 <sup>r</sup>	202,000

<sup>r</sup>Revised.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Includes chemical-grade oxide.

<sup>3</sup>Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4  
U.S. CONSUMPTION OF NICKEL, BY USE<sup>1</sup>

(Metric tons of contained nickel)

Use	2010							Grand total	Grand total in 2009
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)		
Consumption reported:									
Cast irons <sup>2</sup>	61	--	--	--	W	61	227	288	204 <sup>r</sup>
Chemicals and chemical uses	919	--	W	W	W	919	--	919	1,740
Electric, magnet, expansion alloys	211	W	--	--	--	211	1	212	141
Electroplating, sales to platers	7,200	--	--	W	W	7,200	--	7,200	11,500
Nickel-copper and copper-nickel alloys	1,450	--	W	W	W	1,450	2,080	3,530	2,870 <sup>r</sup>
Other nickel and nickel alloys	15,900	W	W	--	52	15,900	W	15,900	20,100 <sup>r</sup>
Steel:									
Stainless and heat resistant	33,500	11,100	W	--	163	44,700	94,700	139,000	104,000
Alloys, excludes stainless	W	W	--	--	--	W	1,430	1,430	6,330 <sup>r</sup>
Superalloys	20,100	W	--	1	593	20,700	W	20,700	13,000 <sup>r</sup>
Other <sup>3</sup>	4,330	323	212	1,270	214	6,350	6,140	12,500	4,180 <sup>r</sup>
Total	83,600	11,400	212	1,280	1,020	97,500	105,000	202,000	164,000 <sup>r</sup>

<sup>r</sup>Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Under investigation.

<sup>3</sup>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<sup>1</sup>

(Metric tons of contained nickel)

Form	2009	2010
Primary:		
Metal	6,330 <sup>r</sup>	8,350
Ferronickel	733	821
Oxide and oxide sinter	75 <sup>r</sup>	82
Chemicals	1,350	1,840
Other	96 <sup>r</sup>	91
Total	8,580 <sup>r</sup>	11,200
Secondary, scrap	5,520 <sup>r</sup>	6,140
Grand total	14,100 <sup>r</sup>	17,300

<sup>r</sup>Revised.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 6  
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS<sup>1</sup>

Class	2009		2010	
	Quantity (metric tons of contained nickel)	Value (thousands)	Quantity (metric tons of contained nickel)	Value (thousands)
<b>Primary:</b>				
Unwrought:				
Cathodes, pellets, briquets, shot	1,100	\$16,800	1,310	\$28,300
Ferronickel	32	1,050	30	1,280
Powder and flakes	1,110	46,700	1,530	67,000
Metallurgical-grade oxide <sup>2</sup>	627	4,850	5,440	33,000
Chemicals: <sup>2</sup>				
Catalysts	2,870	221,000	2,920	184,000
Salts <sup>3</sup>	1,280	22,500	1,410	31,100
Total	7,020	313,000	12,600	345,000
<b>Secondary:<sup>2</sup></b>				
Stainless steel scrap	84,800	777,000	70,300	936,000
Waste and scrap	5,170	36,200	10,000	95,000
Total	90,000	814,000	80,300	1,030,000
Grand total	97,000	1,130,000	93,000	1,380,000
<b>Wrought, not alloyed:</b>				
Bars, rods, profiles, wire	233	6,510	305	7,960
Sheets, strip, foil	546	13,100	548	17,000
Tubes and pipes	197	4,630	1,050	10,400
Total	975	24,200	1,900	35,400
<b>Alloyed, gross weight:</b>				
Unwrought alloyed ingot	5,740	128,000	4,510	108,000
Bars, rods, profiles, wire	12,700	414,000	15,200	507,000
Sheets, strip, foil	6,240	197,000	9,270	282,000
Tubes and pipes	1,920	106,000	2,300	99,200
Other alloyed articles	4,110	277,000	3,250	324,000
Total	30,700	1,120,000	34,500	1,320,000

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

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

<sup>3</sup>Excludes nickel carbonate.

Source: U.S. Census Bureau.

TABLE 7  
U.S. EXPORTS OF NICKEL PRODUCTS, BY COUNTRY<sup>1</sup>

(Metric tons of contained nickel)<sup>2</sup>

Country	2010							Total in 2009	Wrought nickel in 2010 <sup>4</sup>	
	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical- grade oxide <sup>3</sup>	Waste and scrap	Stainless steel scrap	Chemicals			Total
Australia	--	10	--	--	639	5	9	663	426	3
Belgium	18	4	(5)	12	62	108	328	532	431	1
Brazil	149	41	(5)	--	--	2	203	395	409	34
Canada	23	146	--	2,030	5,920	1,610	860	10,600	5,700	256
China	4	199	--	2	74	6,460	257	7,000	18,700	71
Colombia	52	19	--	--	--	4	26	101	74	35
Finland	--	(5)	--	--	21	3,180	--	3,210	2,260	1
France	--	28	--	--	10	45	3	86	77	9
Germany	6	349	--	2	294	25	230	906	657	56
India	2	92	--	2	29	1,870	272	2,270	9,460	9
Italy	--	2	--	--	9	23	32	66	52	(5)
Japan	12	60	--	3,370	1,610	5,780	88	10,900	3,690	43
Korea, Republic of	3	60	--	(5)	24	10,500	55	10,700	11,800	273
Mexico	848	38	(5)	(5)	5	72	728	1,690	1,180	133
Netherlands	1	2	--	--	356	893	77	1,330	393	68
South Africa	1	3	--	2	--	--	12	18	12	(5)
Spain	--	2	--	--	--	974	17	993	814	6
Sweden	--	8	--	--	122	214	(5)	344	380	--
Taiwan	10	26	--	(5)	19	33,900	186	34,100	29,800	37
Thailand	--	87	(5)	--	2	196	39	324	2,260	9
United Kingdom	94	94	27	3	762	117	102	1,200	708	48
Other	90	259	3	25	82	4,310	797	5,570	7,650	812
Total	1,310	1,530	30	5,440	10,000	70,300	4,320	93,000	97,000	1,900

-- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemicals category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfate, 22%. Other salts and various catalysts are assumed to be 22% nickel.

<sup>3</sup>Chemical-grade oxide is included in the "Chemicals" category.

<sup>4</sup>Excluded from "2010, total."

<sup>5</sup>Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 8  
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS<sup>1</sup>

Class	2009		2010	
	Quantity (metric tons of contained nickel)	Value (thousands)	Quantity (metric tons of contained nickel)	Value (thousands)
<b>Primary:</b>				
Unwrought:				
Cathodes, pellets, briquets, shot	85,500	\$1,210,000	110,000	\$2,320,000
Ferronickel	6,200	84,900	9,420	186,000
Powder and flakes	4,450	83,700	6,290	163,000
Metallurgical-grade oxide <sup>2</sup>	799	10,800	77	1,610
Chemicals: <sup>2</sup>				
Catalysts	1,900	78,200	1,690	85,500
Salts <sup>3</sup>	1,010	17,400	1,440	33,000
Total	99,900	1,480,000	129,000	2,790,000
<b>Secondary:<sup>2</sup></b>				
Stainless steel scrap	9,310	138,000	14,600	305,000
Waste and scrap	8,430	112,000	9,130	167,000
Total	17,700	249,000	23,800	472,000
Grand total	118,000	1,730,000	153,000	3,260,000
<b>Wrought, not alloyed:</b>				
Bars, rods, profiles, wire	131	4,260	248	8,360
Sheets, strip, foil	195	5,180	340	9,810
Tubes and pipes	83	4,590	89	2,960
Total	409	14,000	677	21,100
<b>Alloyed, gross weight:</b>				
Unwrought alloyed ingot	4,590	63,600	6,860	135,000
Bars, rods, profiles, wire	6,450	151,000	8,540	210,000
Sheets, strip, foil	1,790	41,900	2,570	57,700
Tubes and pipes	1,670	95,500	1,680	64,000
Other alloyed articles	2,820	87,700	1,830	98,900
Total	17,300	439,000	21,500	565,000

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>The nickel contents are as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts, which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel; stainless steel scrap, 7.5% nickel.

<sup>3</sup>Excludes nickel carbonate.

Source: U.S. Census Bureau.

TABLE 9  
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY<sup>1</sup>

(Metric tons of contained nickel)<sup>2</sup>

Country	2010							Total in 2009	Wrought nickel in 2010 <sup>4</sup>	
	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical- grade oxide <sup>3</sup>	Waste and scrap	Stainless steel scrap	Chemicals			Total
Australia	16,300	603	--	65	67	--	--	17,000	10,600	--
Belgium	--	165	--	--	5	3	208	381	426	(5)
Brazil	3,410	--	--	--	110	35	--	3,550	1,770	--
Canada	17,300	1,680	19	7	1,920	8,510	95	29,500	46,700	7
Colombia	--	--	5,210	--	10	4	--	5,230	3,800	--
Dominican Republic	--	--	--	--	11	16	--	27	238	--
Finland	5,900	16	--	--	(5)	--	357	6,270	5,780	--
France	1,400	1	--	--	1,010	8	378	2,800	2,420	223
Germany	1,050	108	--	--	761	--	343	2,260	1,230	237
Indonesia	--	--	546	--	--	--	3	549	149	--
Israel	--	13	--	--	212	24	--	249	94	--
Italy	--	10	--	--	108	--	40	158	34 <sup>r</sup>	3
Japan	1,130	132	--	--	406	3	121	1,790	1,040	27
Mexico	4	--	1	--	678	5,290	24	6,000	2,710	(5)
Netherlands <sup>6</sup>	62	20	--	(5)	106	--	481	668	342	1
New Caledonia	--	--	3,530	--	--	--	--	3,530	1,800	--
Norway	25,000	--	--	--	--	--	--	25,000	11,300	--
Russia	32,300	1,390	--	--	114	--	--	33,800	20,700	(5)
South Africa	422	284	108	--	--	--	--	814	585	--
Spain	--	--	--	--	83	--	(5)	83	65 <sup>r</sup>	2
Taiwan	--	1	--	--	122	271	(5)	394	146	--
United Kingdom	3,140	1,670	--	6	1,860	77	126	6,870	2,580	36
Zimbabwe	753	--	--	--	--	--	9	762	514	--
Other	1,980	204	--	--	1,560	396	937	5,070	2,510	141
Total	110,000	6,290	9,420	77	9,130	14,600	3,120	153,000	118,000	677

<sup>r</sup>Revised. -- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>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.

<sup>3</sup>Primarily oxide, rondelles, and sinter.

<sup>4</sup>Excluded from "2010, total."

<sup>5</sup>Less than ½ unit.

<sup>6</sup>The different nickel products (cathode, powder, etc.) 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<sup>1</sup>

(Metric tons of contained nickel)

Country and products <sup>2</sup>	2006	2007	2008	2009	2010
Albania, laterite ore <sup>e</sup>	790	3,700	3,500	3,500	3,500
Australia, ores and concentrate <sup>3</sup>	185,000	184,900	199,200	165,000	170,000 <sup>e</sup>
Botswana, ore milled <sup>e</sup>	38,000	27,600	28,940 <sup>4</sup>	28,595 <sup>4</sup>	28,000
Brazil, ore	82,492	58,317	67,116 <sup>r</sup>	41,059 <sup>r</sup>	108,983 <sup>p</sup>
Burma, ore <sup>e</sup>	10	10	10	10	10
Canada, concentrate	232,948	254,915	259,651	136,594	158,376 <sup>p</sup>
China <sup>e</sup>	82,100	67,000	79,500 <sup>r</sup>	84,800 <sup>r</sup>	80,000
Colombia, laterite ore	94,105	75,864 <sup>r</sup>	64,200 <sup>r</sup>	79,900 <sup>r,e</sup>	76,200 <sup>e</sup>
Cuba, oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor <sup>5</sup>	73,371	73,934	67,265	70,000 <sup>r,e</sup>	71,000 <sup>e</sup>
Dominican Republic, laterite ore	47,516	47,125	31,300	500 <sup>r</sup>	--
Finland, concentrate <sup>6</sup>	2,985	3,465 <sup>r</sup>	4,303	4,400 <sup>e</sup>	4,000 <sup>e</sup>
Greece, laterite ore	21,670	21,190	18,646 <sup>r</sup>	10,203 <sup>r</sup>	16,345 <sup>p</sup>
Indonesia, laterite ore <sup>e</sup>	157,200 <sup>r,4</sup>	229,200 <sup>r,4</sup>	219,300 <sup>r</sup>	202,800	235,800
Kazakhstan, laterite ore <sup>e</sup>	200	200	500	500	500
Kosovo, laterite ore	--	1,820	3,660 <sup>7</sup>	10,500 <sup>r,7</sup>	9,080 <sup>7</sup>
Macedonia, ferronickel produced <sup>8</sup>	10,942	15,321	15,026	12,000 <sup>r</sup>	14,000 <sup>e</sup>
Madagascar, laterite ore	--	--	--	--	2,100 <sup>e</sup>
Morocco, nickel sulfate <sup>e</sup>	80 <sup>4</sup>	80 <sup>r</sup>	100	100	100
New Caledonia, ore	102,986	125,364	102,583	92,570 <sup>r</sup>	129,983
Norway, concentrate	362 <sup>r</sup>	246 <sup>r</sup>	377	336 <sup>r</sup>	350
Philippines:					
Ore	56,463 <sup>r</sup>	81,288 <sup>r</sup>	70,082	122,709 <sup>r</sup>	153,679
Concentrate <sup>9</sup>	8,242	10,079	10,562	17,035	19,312
Total	64,705 <sup>r</sup>	91,367 <sup>r</sup>	80,644	139,744 <sup>r</sup>	172,991
Russia, marketable mine production:					
Laterite ore <sup>10</sup>	37,758 <sup>r</sup>	45,687 <sup>r</sup>	36,804 <sup>r</sup>	32,298 <sup>r</sup>	41,184
Sulfide concentrate <sup>11</sup>	239,231	234,083	229,765 <sup>r</sup>	229,493	228,093
Total	276,989 <sup>r</sup>	279,770 <sup>r</sup>	266,569 <sup>r</sup>	261,791 <sup>r</sup>	269,277
South Africa, concentrate	41,599	37,917	31,675	34,605 <sup>r</sup>	39,960
Spain, concentrate	6,398	6,772	8,136	8,029	6,296
Turkey, laterite ore <sup>e,12</sup>	1,500	--	--	--	--
Ukraine, laterite ore <sup>e</sup>	12,000	12,000	8,000	--	--
Venezuela, laterite ore	21,200	18,900	13,000	13,200	11,400
Zambia, concentrate <sup>13</sup>	--	--	751	280 <sup>r,e</sup>	2,809
Zimbabwe, concentrate	8,825	8,582	6,354	4,858 <sup>r</sup>	6,200
Grand total	1,570,000	1,650,000 <sup>r</sup>	1,580,000 <sup>r</sup>	1,410,000 <sup>r</sup>	1,620,000
Of which:					
Concentrate <sup>14</sup>	541,000	556,000	552,000	436,000	465,000
Ore and ore milled	280,000 <sup>r</sup>	293,000 <sup>r</sup>	269,000 <sup>r</sup>	285,000 <sup>r</sup>	421,000
Laterite ore	394,000	456,000 <sup>r</sup>	399,000 <sup>r</sup>	353,000 <sup>r</sup>	396,000
Ferronickel produced	10,900	15,300	15,000	12,000	14,000 <sup>e</sup>
Nickel sulfate <sup>e</sup>	80 <sup>4</sup>	80 <sup>r</sup>	100	100	100
Unspecified and (or) undifferentiated	340,000	326,000	346,000 <sup>r</sup>	320,000 <sup>r</sup>	321,000

<sup>e</sup>Estimated. <sup>p</sup>Preliminary. <sup>r</sup>Revised. -- Zero.

<sup>1</sup>World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>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. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through January 31, 2012.

<sup>3</sup>Australian Bureau of Agricultural and Resource Economics (ABARE) data for mines in Western Australia and Tasmania.

<sup>4</sup>Reported figure.

TABLE 10—Continued  
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY<sup>1</sup>

<sup>5</sup>The Government of Cuba reports figures of nickel-cobalt content of granular and powder oxide, oxide sinter, and sulfide production. The cobalt content of reported nickel-cobalt production was determined to be 1.2% for granular and powdered oxide, 1.2% for oxide sinter, 7.6% for sulfide precipitate, and 33% for leach ammoniacal precipitate. The remainder of reported figures represents the nickel content.

<sup>6</sup>The gross weight of concentrates processed in Finland from domestic ores was, in metric tons, as follows: 2006—40,474; 2007—44,824; 2008—43,038; 2009—43,000 (estimated); and 2010—40,800 (estimated).

<sup>7</sup>On February 17, 2008, the Kosovo Assembly declared independence from Serbia.

<sup>8</sup>Cunco 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.

<sup>9</sup>Nickel content of concentrate produced at Rio Tuba in 2006–10 by Coral Bay Nickel Corp.

<sup>10</sup>Nickel content of ore mined in the Ural Mountains region.

<sup>11</sup>Nickel content of concentrate produced on the Kola and Taimyr Peninsulas.

<sup>12</sup>European Nickel PLC began shipping laterite ore from the Caldag Mine to the ferronickel smelter of Larco General Mining and Metallurgical Company S.A. in Greece in 2006.

<sup>13</sup>Albidon Limited concentrates were shipped to Jinchuan, China. First production was in June 2008. Anticipated specifications for concentrates are 13% nickel and 0.7% cobalt. Concentrate production comes from company quarterly reports.

<sup>14</sup>Includes “Russia, sulfide concentrate.”

TABLE 11  
NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY<sup>1,2</sup>

(Metric tons of contained nickel)

Country	2006	2007	2008	2009	2010
<b>Matte:</b>					
Australia <sup>3</sup>	39,561	41,612	31,085	35,441	76,290 <sup>P</sup>
Botswana	26,762	22,844	28,940	29,616	29,000
Brazil <sup>4</sup>	5,416	3,401	8,328 <sup>r</sup>	8,518 <sup>r</sup>	14,308 <sup>P</sup>
Canada <sup>5</sup>	56,628	73,922	76,908	68,972	70,127 <sup>P</sup>
China <sup>6</sup>	758	1,980	3,240	--	1
Indonesia <sup>7</sup>	72,782	77,928	73,356	68,228 <sup>r</sup>	77,186
New Caledonia	13,655	14,842	13,564	13,902	13,917
Russia <sup>8</sup>	1,300 <sup>9</sup>	670	600	240	206
Zimbabwe <sup>e,10</sup>	1,600	1,600 <sup>r</sup>	1,700 <sup>r</sup>	2,200 <sup>r</sup>	3,500
Total	218,000	239,000	238,000 <sup>r</sup>	227,000 <sup>r</sup>	285,000
<b>Other, Cuba:<sup>11</sup></b>					
Sulfide precipitate	30,967	31,116	32,465	33,600 <sup>r</sup>	34,000 <sup>P</sup>
Ammoniacal liquor precipitate	3,283	2,907	322	300 <sup>e</sup>	300 <sup>e</sup>
Total	34,250	34,023	32,787	33,900 <sup>r,e</sup>	34,300 <sup>e</sup>

<sup>e</sup>Estimated. <sup>P</sup>Preliminary. <sup>r</sup>Revised. -- Zero.

<sup>1</sup>Table includes data available through January 31, 2012. Data represent nickel content of matte and other intermediate materials produced.

<sup>2</sup>World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

<sup>3</sup>Figures exclude toll-refined material. Total matte production on a contained nickel basis, in metric tons, was as follows: 2006—39,000; 2007—42,000; 2008—31,000; 2009—28,000 (revised); and 2010—54,000.

<sup>4</sup>Represents the output of the Fortaleza smelter. All of the Fortaleza matte is shipped to Finland for further processing.

<sup>5</sup>Nickel content of reported exports. Matte from the smelter at Falconbridge typically assays 55% nickel.

<sup>6</sup>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: 2006—99,800; 2007—105,000; 2008—114,000 (revised); 2009—120,000 (revised); and 2010—125,000.

<sup>7</sup>Represents the nickel output of the Soroako smelter. The Soroako matte is shipped to Japan for further processing and contains on average 78% nickel.

<sup>8</sup>Primarily exports to China. Sources: International Nickel Study Group; United Nations Statistics Division.

<sup>9</sup>Reported figure.

<sup>10</sup>Zimplats material shipped to the Impala Refinery at Springs, South Africa.

<sup>11</sup>Corrected to remove coproduct cobalt.

TABLE 12  
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT<sup>1,2</sup>

(Metric tons of contained nickel)

Country and product <sup>3</sup>	2006	2007	2008	2009	2010
Australia:					
Metal	105,100	100,300	89,500	123,200	98,000
Unspecified <sup>4</sup>	11,400	14,200	19,400	8,000	10,000
Total	116,500	114,500	108,900	131,200	108,000
Austria, ferronickel and ferronickel molybdenum <sup>c</sup>	900	900	800 <sup>r</sup>	700	600
Brazil: <sup>5</sup>					
Ferronickel	9,814	9,918	9,136 <sup>r</sup>	9,427 <sup>r</sup>	8,465 <sup>p</sup>
Metal	21,339	21,635	18,530	16,598 <sup>r</sup>	19,111 <sup>p</sup>
Total	31,153	31,553	27,666 <sup>r</sup>	26,025 <sup>r</sup>	27,576 <sup>p</sup>
Canada, unspecified <sup>6</sup>	146,899	153,647	167,732	116,909	105,413 <sup>p</sup>
China: <sup>7</sup>					
Ferronickel and high nickel pig iron	31,000	84,500	70,900	100,000	150,000
Metal	102,000	116,000	129,000	165,000	172,000
Chemicals and unspecified <sup>c</sup>	5,000	6,000 <sup>s</sup>	8,000 <sup>s</sup>	8,000	8,500
Total	138,000	206,500	207,900	273,000	330,500
Colombia, ferronickel	51,137	49,314	41,636	51,802	49,443
Cuba, oxide sinter and oxides <sup>9</sup>	39,121	39,911	34,478	32,800 <sup>r,c</sup>	34,000 <sup>e</sup>
Dominican Republic, ferronickel	29,675	29,130 <sup>r</sup>	18,782 <sup>r</sup>	--	--
Finland: <sup>10</sup>					
Metal	42,299	49,758 <sup>r</sup>	36,181 <sup>r</sup>	41,848	42,000 <sup>e</sup>
Chemicals and unspecified	5,170	5,206 <sup>r</sup>	6,855 <sup>r</sup>	5,000	7,160 <sup>e</sup>
Total	47,469	54,964 <sup>r</sup>	43,036 <sup>r</sup>	46,848	49,159 <sup>p</sup>
France:					
Metal <sup>e</sup>	11,700 <sup>r,s</sup>	11,200	11,400 <sup>r</sup>	12,000 <sup>r,s</sup>	10,800
Chemicals <sup>c</sup>	1,620 <sup>r</sup>	2,020 <sup>r</sup>	1,840 <sup>r</sup>	1,960 <sup>r</sup>	2,080
Total <sup>11</sup>	13,319 <sup>r</sup>	13,218 <sup>r</sup>	13,236 <sup>r</sup>	13,955 <sup>r</sup>	12,879
Greece, ferronickel	17,740	18,670	16,650 <sup>r</sup>	8,269 <sup>r</sup>	13,975
India: <sup>12</sup>					
Ferronickel	(13)	(13)	(13)	(13)	(13)
Ferronickel magnesium	41	52	93	88	90
Nickel sulfate	(14)	(14)	(14)	(14)	(14)
Total	41	52	93	88	90
Indonesia, ferronickel	14,474	18,532	17,566	12,550	18,688
Japan:					
Ferronickel	66,668	68,346	59,259	54,491 <sup>r</sup>	64,349
Metal	29,254	30,402	34,861	29,351 <sup>r</sup>	40,228
Oxide sinter	53,800 <sup>r</sup>	60,151	60,000 <sup>r,c</sup>	58,000 <sup>r,c</sup>	59,000 <sup>e</sup>
Chemicals	2,531	2,270	2,333	1,669 <sup>r</sup>	2,497
Total	152,253 <sup>r</sup>	161,169	156,000 <sup>r,c</sup>	144,000 <sup>r,c</sup>	166,000 <sup>e</sup>
Korea, Republic of:					
Ferronickel	--	--	2,506	21,609	20,965 <sup>p</sup>
Metal	(15)	(15)	(15)	(15)	(15)
Total	(15)	(15)	2,506	21,609	20,965 <sup>p</sup>
Kosovo, ferronickel <sup>c</sup>	--	800	5,600 <sup>r,16</sup>	6,360 <sup>r,16</sup>	7,000
Macedonia, ferronickel	10,942	15,321	15,026	12,000 <sup>r</sup>	14,000 <sup>e</sup>
Morocco, chemicals <sup>c</sup>	125	125	125	125	125
New Caledonia, ferronickel	48,723	44,954	37,467	38,230	39,802
Norway, metal	81,974	87,590	88,741	88,577	92,185
Poland, chemicals <sup>c,17</sup>	465 <sup>s</sup>	475	475	475	475
Russia:					
Ferronickel					
High-nickel	14,436	17,111	16,158	15,565	16,799
Other <sup>18</sup>	4,490	4,690	4,905	5,125	5,330

See footnotes at end of table.

TABLE 12—Continued  
 NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT<sup>1,2</sup>

(Metric tons of contained nickel)

Country and product <sup>3</sup>	2006	2007	2008	2009	2010
Russia—Continued:					
Metal	255,045	248,363	242,409	239,269 <sup>r</sup>	245,543
Oxide sinter	2,713	235	--	--	--
Chemicals <sup>c</sup>	3,500	3,100	2,900	2,700	2,700
Total	280,184	273,499	266,372	262,659 <sup>r</sup>	270,372
South Africa:					
Ferronickel, high-nickel	100	5,000	4,300	800	780
Metal	42,000 <sup>r</sup>	39,800 <sup>r</sup>	32,300 <sup>r</sup>	36,500 <sup>r</sup>	35,700 <sup>e</sup>
Chemicals <sup>e, 19</sup>	6,360 <sup>r</sup>	6,610 <sup>r</sup>	4,450 <sup>r</sup>	4,850 <sup>r</sup>	4,790
Total	48,460 <sup>r</sup>	51,410 <sup>r</sup>	41,050 <sup>r</sup>	42,150 <sup>r</sup>	41,300 <sup>e</sup>
Taiwan, metal	(15)	(15)	(15)	(15)	(15)
Ukraine, ferronickel <sup>20</sup>	15,223	14,211 <sup>r</sup>	16,224	12,392	12,400 <sup>e</sup>
United Kingdom, metal <sup>21</sup>	36,770	34,064	38,700 <sup>r</sup>	38,000 <sup>r, e</sup>	38,000 <sup>e</sup>
Venezuela, ferronickel	16,600	15,700	10,900	10,400	11,700 <sup>p</sup>
Zimbabwe, metal: <sup>e</sup>					
Refined from domestic nickel ore	5,510 <sup>8</sup>	4,500	3,400	--	--
Toll refined from imported nickel feed <sup>22</sup>	9,000	9,500	10,300	6,000 <sup>r</sup>	4,064 <sup>8</sup>
Total	14,510 <sup>8</sup>	14,000	13,700	6,000 <sup>r</sup>	4,064 <sup>8</sup>
Grand total	1,350,000	1,440,000	1,390,000 <sup>r</sup>	1,400,000 <sup>r</sup>	1,470,000
Of which:					
Ferronickel, including ferronickel magnesium, ferronickel molybdenum, and high nickel pig iron	332,000	397,000 <sup>r</sup>	348,000 <sup>r</sup>	360,000 <sup>r</sup>	434,000
Metal	742,000 <sup>r</sup>	753,000 <sup>r</sup>	735,000 <sup>r</sup>	796,000 <sup>r</sup>	798,000
Oxide sinter	95,600 <sup>r</sup>	100,000	94,500 <sup>r</sup>	90,800 <sup>r</sup>	93,000
Chemicals, including nickel sulfate	14,600 <sup>r</sup>	14,600 <sup>r</sup>	12,100 <sup>r</sup>	11,800 <sup>r</sup>	12,700
Unspecified	168,000	179,000	202,000 <sup>r</sup>	138,000	131,000

<sup>e</sup>Estimated. <sup>p</sup>Preliminary. <sup>r</sup>Revised. -- Zero.

<sup>1</sup>World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Table includes data available through August 12, 2011.

<sup>3</sup>In addition to the countries listed, North Korea is thought to have produced metallic nickel and (or) ferronickel, but information is inadequate to make reliable estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries producing matte for export are listed in table 11.

<sup>4</sup>Class II products with a nickel content of less than 99%. Includes oxides and oxide sinter. Excludes intermediate nickel-cobalt sulfide matte, regulus, and speiss for further refining.

<sup>5</sup>Brazil produced nickel carbonate (an intermediate product for metal production), in metric tons: 2006—21,630; 2007—20,796; 2008—18,580 (revised); 2009—16,766 (revised); and 2010—21,800 (estimated).

<sup>6</sup>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 15.

<sup>7</sup>Preliminary figures for ferronickel and chemicals were derived from data published by Beijing Antaika 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. In 2006–10, China also produced nickeliferous pig iron from lateritic ores imported from Indonesia, New Caledonia, and the Philippines.

<sup>8</sup>Reported figure.

<sup>9</sup>Cuba also produces nickel sulfide and ammoniacal liquor precipitate, but because they are used as feed material elsewhere, they are not included to avoid double counting. More information can be found in table 11.

<sup>10</sup>Most of the production is extracted from imported raw materials.

<sup>11</sup>Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.

<sup>12</sup>India's fiscal year ending March 31 of that year stated.

<sup>13</sup>Vidarbha Nickel Pvt. Ltd. of Nagpur, Maharashtra State, has been producing ferronickel from spent nickel catalysts, but no production data were available. The ferronickel typically contains 47% to 50% nickel.

<sup>14</sup>In India, nickel sulfate has been produced in the past as a byproduct at the Ghatsila copper smelter in Jharkhand State. The facility is capable of producing 390 tons (gross weight) per year of nickel sulfate, but no production has been reported since 2005.

TABLE 12—Continued  
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT<sup>1,2</sup>

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<sup>15</sup>Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: Republic of Korea: 2006—28,085; 2007—28,675; 2008—28,653; 2009—20,900 (revised estimate); and 2010—22,000 (estimated). Taiwan: 2006—11,000 (estimated); 2007—11,000 (estimated); 2008—11,000 (estimated); 2009—11,000 (estimated); and 2010—11,000 (estimated).

<sup>16</sup>On February 17, 2008, the Kosovo Assembly declared independence from Serbia.

<sup>17</sup>Nickel content of nickel sulfate. 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.

<sup>18</sup>Includes ferronickel chromium and Ni-resist cast iron.

<sup>19</sup>Includes nickel sulfate plus exported metal in concentrate.

<sup>20</sup>May include nickel in remelt alloys derived from scrap.

<sup>21</sup>Tonnages include nickel contents of chemicals.

<sup>22</sup>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 2016

Projected year of first production	Country (state/province)	Project and company <sup>1</sup>	Resource grade (% nickel)	Estimated resources (thousand metric tons) <sup>2</sup>	Annual production capacity (metric tons of contained nickel)	Nickel product
2010–11	Brazil (Pará)	Onca-Puma	1.73	110,000	53,000	Ferronickel.
		Vale Nickel	1.76	59,000		
2010–12	New Caledonia (Southern)	Vale Nouvelle-Calédonie (formerly Goro) <sup>3</sup>	1.34	96,000	60,000	Nickel-cobalt hydroxide, initially. Nickel oxide, later.
		Vale Nickel, Société de Participation Minière du Sud Calédonien S.A.S., and SUMIC	2.01	24,000		
		Netherlands Nickel B.V. (a joint venture of Sumitomo Metal Mining Co., Ltd. and Mitsui & Co., Ltd.)	1.70	83,000		
2011	Australia (Western Australia)	Ravensthorpe (restart)	0.73	120,000	39,000	Nickel-cobalt hydroxide.
		First Quantum Minerals Ltd.	0.58	150,000		
			0.53	110,000		
2011	Brazil (Goias)	Barro Alto	1.50	9,100	36,000	Ferronickel.
		Anglo American plc	1.22	9,800		
			1.42	63,000		
2011–13	Madagascar (Moramanga)	Ambatovy (Ambatovy and Analamay deposits)	1.05	84,000 <sup>4</sup>	60,000	Nickel metal powder and briquettes.
		Sherritt International Corp. (40%), Korea Resources Corp. (27.5%), Sumitomo Corp. (27.5%), and SNC-Lavalin Inc. (5%)	0.84	22,000		
			1.08	29,000		
2012	Burma (Thabeikkyin, Mandalay)	Tagaung Taung China Nonferrous Metals Mining Group Co., Ltd. (CNMC), Government of Burma, and Taiyuan Iron and Steel (Group) Co., Ltd. (TISCO)	2.02	40,000	22,000	Ferronickel.
2012	Papua New Guinea (Madang)	Ramu	0.93	42,000	31,000	Nickel-cobalt hydroxide.
		Metallurgical Group Corp. of China Ltd.	1.07	30,000		
		consortium (85%), <sup>5</sup> Highlands Pacific Ltd. (8.56%), and Mineral Resources Development Co. (6.44%)	1.04	71,000		
2012	Philippines (Surigao del Norte and Surigao del Sur)	Adlay-Cagdianao-Tandawa	1.61	5,800	20,000	Direct shipping ore.
		Surigao Integrated Resources Corp. (assignment from CTP Construction and Mining Corp.)	1.58	13,000		
2012	Philippines (Zambales)	Acoje and Zambales—Stage 1	1.04	22,000 <sup>6</sup>	24,500	Do.
		DMCI Holdings, Inc. and ENK PLC (formerly European Nickel PLC) <sup>7</sup>	1.03	4,200 <sup>6</sup>		
			1.25	21,000 <sup>8</sup>		
			1.03	2,200 <sup>8</sup>		
2013	Australia (Queensland)	Lucky Break (Circular Laterite and Dingo Dam)	0.82	590,000	730	Nickel carbonate.
		Metallica Minerals Ltd. (50%) and Metals Finance Ltd. (50%)	0.82	48,000		
			0.75	490,000		
2013	New Caledonia (Northern)	Koniambo (sapolite ores)	2.54	21,000	60,000	Ferronickel.
		Société Minière du Sud Pacifique S.A. (51%)	2.45	54,000		
		and Xstrata Nickel (49%)	2.50	83,000		
2013	Philippines (Surigao del Norte and Surigao del Sur)	Taganito mine and hydrometallurgical processing plant	1.14	83,000 <sup>9</sup>	30,000	Nickel-cobalt sulfide.
		Mine ownership—Nickel Asia Corp. (65%), Pacific Metals Co., Ltd. (33.5%), and Sōjitsu Kabushiki-gaisha (SOJITZ) Corporation (1.5%) Hydrometallurgical processing plant ownership—Sumitomo Metal Mining Co., Ltd. (62.5%), Nickel Asia Corp. (22.5%), and Mitsui & Co., Ltd. (15%)	0.95	360 <sup>9</sup>		

See footnotes at end of table.

TABLE 13—Continued  
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAREND 2016

Projected year of first production	Country (state/province)	Project and company <sup>1</sup>	Resource grade (% nickel)	Estimated resources (thousand metric tons) <sup>2</sup>	Annual production capacity (metric tons of contained nickel)	Nickel product
2014	Australia (Tasmania)	Barnes Hill, Mount Vulcan, and Scott's Hill Proto Resources & Investments Ltd. <sup>10</sup> and Metals Finance Ltd.	0.82	6,600	2,000	Metal.
2014	Philippines (Romblon)	Romblon (Sibuyan Island) Pelican Resources Ltd.	1.54	7,300	9,000	Direct shipping ore.
2015	Australia (Queensland)	Marlborough (Coorumburra, Slopeaway, and Whereat) <sup>11</sup> —Stage 1 Gladstone Pacific Nickel Ltd.	0.99 0.91 0.70	12,000 43,000 70,000	63,000	Metal.
2015	Australia (Queensland)	NORNICO-Greenvale (Bell Creek, Greenvale, Kokomo, Lucknow, and Minnamoolka deposits) Metallica Minerals Ltd.	0.96 0.77 0.70	14,000 29,000 6,000	10,000	Nickel-cobalt hydroxide.
2015	Cuba (Holguin)	Las Camariocas-Yamaguey Quality Cuba S.A.	1.32	110,000	21,000	Ferronickel.
2015	Indonesia (Sulawesi)	Mandiodo PT Antam (Persero) Tbk	2.10 1.50	5,000 <sup>12</sup> 28,000 <sup>13</sup>	12,000	Nickel pig iron.
2015	Do.	North Konawe Jilin Horoc Non-Ferrous Metal Group Co., Ltd., PT Billy Indonesia, and Government of Southeast Sulawesi	1.50	100,000	20,000	Ferronickel.
2016	Australia (Western Australia)	Mt. Thirsty Barra Resources Ltd. (50%) and Fission Energy Ltd. (50%)	0.60 0.51	17,000 15,000	9,000	Nickel-cobalt sulfide.
2016	Do.	NiWest (Eucalyptus, Hepi, Mt. Kilkenny, and Wanbanna) GME Resources Ltd.	1.04 0.99 0.96	34,000 24,000 21,000	30,000	Do.
2016	Australia (junction of the Western Australian, South Australian, and Northern Territory borders)	Wingellina Metals X Ltd.	1.00 0.97 0.97	69,000 99,000 16,000	40,000	Nickel-cobalt hydroxide.
2016	Cameroon (East Province)	Mada and Nkamouna Geovic Cameroon PLC. (60%) and National Investment Corp. (40%)	0.68 0.67 0.19 0.59 0.58	60,000 <sup>14</sup> 21,000 <sup>14</sup> 20,000 <sup>14</sup> 40,000 <sup>15</sup> 180,000 <sup>15</sup>	3,200	Cobalt-nickel sulfide.
2016	New Caledonia (Nakety-Bogota)	Nakety-Bogota <sup>16</sup> Société Gestion—Exploitation des Mines de Nickel (GEMINI S.A.), Société Minière Georges Montagnat S.A., and Société des Mines de la Tontouta (Ballande Group)	1.47 1.50	88,000 <sup>17</sup> 140,000 <sup>18</sup>	52,000	Ore.
2016	Philippines (Agusan del Norte)	Agata (includes Bolobolo-Karihatag and Agata South) Mindoro Resources Ltd.	1.00 1.16 0.95 1.18 0.80 1.11	250 <sup>6</sup> 540 <sup>19</sup> 13,000 <sup>6</sup> 29,000 <sup>19</sup> 680 <sup>6</sup> 1,700 <sup>19</sup>	7,500 14,000	Phase I, direct shipping ore. Phase 2, nickel-cobalt hydroxide.

See footnotes at end of table.

TABLE 13—Continued  
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAREND 2016

Projected year of first production	Country (state/province)	Project and company <sup>1</sup>	Resource grade (% nickel)	Estimated resources (thousand metric tons) <sup>2</sup>	Annual production capacity (metric tons of contained nickel)	Nickel product
2016	Philippines (Mindoro Oriental)	Mindoro I/ Sablayan (Buraboy, Kisluyan, and Shabo areas)	0.85	17,000	53,000	Metal.
			0.86	210,000		
		Aglubang Mining Corp. (local partner) and Intex Resources ASA	0.77	91,000		
2016	Philippines (Zambales)	Acoje and Zambales—Stage 2 DMCI Holdings, Inc. and ENK PLC (formerly European Nickel PLC) <sup>7</sup>	1.12	30,800 <sup>20</sup>	24,000	Nickel-cobalt hydroxide.
2016	Tanzania (Northern/ Lake Victoria)	Dutwa (Wamangola and Ngasamo Hill)	0.90	60,000 <sup>21</sup>	32,000	Nickel-cobalt hydroxide or sulfide.
		African Eagle Resources plc	0.97	38,000 <sup>22</sup>		
2016	Turkey (Manisa)	Caldag VTG Nikel Madencilik San. ve Tic. A.Ş., a subsidiary of OreMine Madencilik (OreMine Resources) San. ve Tic. A.Ş.	1.13	33,000	21,000	Nickel-cobalt hydroxide.

Do. Ditto.

<sup>1</sup>Company names reflect organizational structure as of January 31, 2012. 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. (formerly Companhia Vale do Rio Doce).

<sup>2</sup>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.

<sup>3</sup>On December 19, 2008, the name of the project—Goro—was changed to Vale Inco Nouvelle-Calédonie. Vale Inco Nouvelle-Calédonie was renamed Vale Nouvelle-Calédonie in May 2010.

<sup>4</sup>Data represent mineral resources of only the Ambatovy deposits. Significant additional resources are associated with the Analamay deposits, northeast of the Ambatovy mine area.

<sup>5</sup>The Chinese consortium is owned by Metallurgical Corporation of China Ltd. (61%), Jinchuan Group Ltd. (13%), Jilin Jien Nickel Industry Co., Ltd. (13%), and Jiuquan Iron & Steel Group Co., Ltd. (13%).

<sup>6</sup>Limonite.

<sup>7</sup>In June 2010, European Nickel PLC and Rusina Mining NL merged to form ENK PLC.

<sup>8</sup>Zambales—laterite.

<sup>9</sup>Dry metric tons of limonite. Figures exclude saprolite resources.

<sup>10</sup>Proto Resources & Investments Ltd. was also evaluating the Waite Kauri North laterite deposit near Leonora in Western Australia.

<sup>11</sup>The Marlborough ores would be supplemented with ores from the mines of Société des Mines de la Tontouta and Société Minière Georges Montagnat in New Caledonia.

<sup>12</sup>Measured resources of nickel in saprolite.

<sup>13</sup>Measured resources of nickel in limonite.

<sup>14</sup>Nkamouna deposit—first datum is indicated resources; second is indicated resources; and third is inferred resources.

<sup>15</sup>Mada deposit—first datum is indicated resources; and second is inferred resources.

<sup>16</sup>Ore would be shipped to Queensland for blending with ores from the Marlborough project and subsequent processing.

<sup>17</sup>Nakety.

<sup>18</sup>Bogota.

<sup>19</sup>Saprolite.

<sup>20</sup>Acoje only.

<sup>21</sup>Wamangola deposit inferred resource.

<sup>22</sup>Ngasamo Hill deposit inferred resource.

Sources: Company annual reports, presentations, and press releases; CRU International, Ltd.

TABLE 14  
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAREND 2016

Projected year of first production <sup>1</sup>	Country (state/province)	Project and company <sup>2</sup>	Resource grade (% nickel)	Estimated resources (thousand metric tons) <sup>3</sup>	Annual production capacity (metric tons of contained nickel)	Nickel product
2010–2011	Australia (Western Australia)	Lanfranchi-Deacon Panoramic Resources Ltd.	1.93	6,800	18,000	Ore.
2010–2011	Do.	Prospero Xstrata Nickel Australasia	6.39 6.42 5.03	420 470 450	10,000	Concentrate.
2010–2011	Do.	Sinclair (underground) <sup>4</sup> Xstrata Nickel Australasia	3.88 2.50 2.10	100 830 710	5,500	Do.
2010–2011	Canada (Ontario)	Nickel Rim South Xstrata Nickel	1.65 1.48 1.60	2,800 2,500 15,000	18,000	Do.
2010–2011	Finland (Sotkama)	Sotkama Talvivaara Mining Co. Plc	0.22	1,500	50,000	Nickel-cobalt sulfide.
2010–2011	Canada (Manitoba)	Bucko Lake (restart) CaNickel Mining Ltd.	1.45 1.52 1.34	3,700 2,800 5,500	5,000	Concentrate.
2011	Australia (Western Australia)	Spotted Quoll Underground—Stage I Western Areas NL	4.10	1,700	10,000	Do.
2012	Do.	Cosmic Boy and Diggers <sup>5</sup> Western Areas NL	1.46 <sup>6</sup> 2.40 <sup>7</sup> 1.00 <sup>8</sup>	2,100 380 10,000	7,000	Do.
2012	Canada (Quebec)	Raglan-Kikialik Xstrata Nickel	3.10	1,800	24,000	Do.
2012	Finland (Lappi)	Kevitsa First Quantum Minerals Ltd.	0.29 0.32 0.29	89,000 150,000 35,000	10,000	Do.
2012–2013	Finland (Pohiois)	Outokumpu Copper (Kylahti mine and Luikonlahti mill) Altona Mining Ltd. <sup>9</sup>	0.17 0.20 0.18	620 7,500 310	450	Cobalt-nickel concentrate.
2013	Australia (Western Australia)	Radio Hill and Sholl (bacterial heap leaching) Fox Resources Ltd.	0.59	6,000	7,400	Nickel-cobalt carbonate.
2013	Canada (Ontario)	Fraser Morgan Xstrata Nickel	1.94 1.81 1.70	4,400 2,400 1,800	6,000	Ore.
2013	Do.	Hart Liberty Mines Inc.	1.40	1,500	9,000	Concentrate.
2013	Do.	Totten (plus new Clarabelle mill addition) Vale Nickel	1.33	8,400	8,200	Do.
2013	Canada (Quebec)	Nunavik (South Raglan) [Allammaq, Expo, Ivakkak, Mequillon, Mesamax, and TK deposits] Jilin Jien Nickel Industry Co., Ltd. and Goldbrook Ventures Inc. <sup>10</sup>	0.93 0.93 0.73	560 21,000 5,200	6,800	Do.
2013	China (Xinjiang Autonomous region/ East Tianshan)	Tula'ergen Xinjiang Hami Hexin Mining Ltd.	1.10	100,000	3,000	Do.
2013	United States (Michigan)	Eagle Kennecott Minerals Co. (Rio Tinto Group)	3.47 3.16	3,600 500	17,000	Do.

See footnotes at end of table.

TABLE 14—Continued  
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAREND 2016

Projected year of first production <sup>1</sup>	Country (state/province)	Project and company <sup>2</sup>	Resource grade (% nickel)	Estimated resources (thousand metric tons) <sup>3</sup>	Annual production capacity (metric tons of contained nickel)	Nickel product
2014	Canada (Manitoba)	Makwa (formerly Maskwa) Mustang Minerals Corp. <sup>11</sup>	0.54	9,800	3,700	Do.
2014	Do.	Minago Victory Nickel Inc.	0.56 0.51 0.53	11,000 43,000 15,000	11,000	Do.
2014	Canada (Sudbury)	Copper Cliff Deep Vale Nickel	NA	130,000	NA	Concentrate.
2014	China (Gansu)	Heishan Jinchuan Group Co., Ltd.	0.60	23,000	5,000	Do.
2014	Finland (Oulu)	Kuhmo (Arola, Hietaharju, Peura-aho, Sika-aho, and Vaara) Altona Mining Ltd. <sup>9</sup> and Polar Mining Oy	0.55	6,000	3,000	Do.
2014	United States (Minnesota)	NorthMet PolyMet Mining Corp. and Glencore International AG	0.08 0.08	580,000 230,000	7,100	Concentrate, initially. Byproduct nickel-cobalt hydroxide, later.
2015	Australia (Western Australia)	Mt. Windarra Poseidon Nickel Ltd.	1.24 1.72	910 3,000	7,000	Concentrate.
2015	Do.	New Morning/Daybreak Western Areas NL	3.70 <sup>12</sup> 3.50 <sup>12</sup> 0.90 <sup>13</sup> 0.90 <sup>13</sup>	320 93 1,100 660	3,000	Ore.
2015	Canada (Ontario)	Onaping Depth Xstrata Nickel	2.67 3.60	15,000 1,200	10,000	Do.
2015	Russia (Amur)	Kun-Manie (Falcon, Ikensoe, Maly Krumkon, and Vodorazdelny) Amur Minerals Corp.	0.61 0.48 0.54	3,700 48,000 17,000	16,000	Concentrate.
2015	Tanzania (Kagera region)	Kabanga Barrick Gold Corp. and Xstrata Nickel	2.49 2.72 2.60	14,000 23,000 21,000	40,000	Do.
2015	Vietnam (Son La)	Ban Phuc Asian Mineral Resources Ltd. and Son La Mechanical Engineering JSC	2.68 <sup>12</sup> 1.94 <sup>12</sup> 0.59 <sup>13</sup> 0.56 <sup>13</sup>	1,700 170 13,000 7,400	6,400	Do.
2016	Australia (Western Australia)	Sherlock Bay Australasian Resources Ltd.	0.38 0.39 0.44	9,600 9,400 6,400	8,500	Bioreachate precipitate.
2016	Do.	Sholl B2 Fox Resources Ltd. and Jinchuan Group Ltd.	0.59 0.51	2,300 3,500	3,000	Do.
2016	Botswana (Selebi-Phikwe region)	Dikoloti Discovery Metals Ltd. and Japan Oil, Gas and Metals National Corp.	0.70	4,100	2,000	Nickel-cobalt sulfide.
2016	Canada (British Columbia)	Turnagain Hard Creek Nickel Corp.	0.18 0.16 0.15	59,000 430,000 560,000	24,000	Concentrate.
2016	Canada (Ontario)	Eagle's Nest-McFaulds Lake Noront Resources Ltd. and Baosteel Resources International Co., Ltd.	2.08 1.50 1.10	5,400 5,600 9,000	NA	Do.
2016	Do.	Kenbridge (open pit) Canadian Arrow Mines Ltd.	0.42	45,000	3,900	Do.

See footnotes at end of table.

TABLE 14—Continued  
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAREND 2016

Projected year of first production <sup>1</sup>	Country (state/province)	Project and company <sup>2</sup>	Resource grade (% nickel)	Estimated resources (thousand metric tons) <sup>3</sup>	Annual production capacity (metric tons of contained nickel)	Nickel product
2016	Do.	Victoria QuadraFNX Mining Ltd.	2.20	12,500	NA	Ore.
2016	Canada (Quebec)	Dumont Royal Nickel Corp.	0.29 0.27 0.26	190,000 1,200,000 700,000	30,000	Ferronickel.
2016	Do.	Raglan-Qakimajung Xstrata Nickel	4.52	2,500	11,000	Concentrate.
2016	Canada (Yukon Territory)	Wellgreen Prophecy Platinum Corp. (formerly Pacific Coast Nickel)	0.38 0.69	290,000 14,000	10,000	Do.
2016	Russia (Kola Peninsula)	Vuruchuaivench MMC Norilsk Nickel-Kola MMC	0.23	17,500	NA	Metal.
2016	Russia (Taimyr Peninsula)	Maslovsky MMC Norilsk Nickel-Polar Division	0.33	220,000	18,000	Do.
2016	South Africa (Mpumalanga and Limpopo)	Sheba's Ridge Aquarius Platinum Ltd. (39%), Anglo Platinum Ltd. (35%), and Industrial Development Corp. of South Africa (26%) <sup>14</sup>	0.20 0.18 0.19	80,000 97,000 430,000	24,000	Do.
2016	United States (Minnesota)	Nokomis/ Maturi Extension Birch Lake, Maturi, Spruce Road Twin Metals Minnesota LLC <sup>17</sup> [Duluth Metals Ltd. (60%) and Antofagasta PLC (40%)]	0.20 <sup>15</sup> 0.21 <sup>16</sup> 0.17 <sup>18</sup> 0.16 <sup>19</sup> 0.25 <sup>20</sup> 0.21 <sup>21</sup>	550,000 270,000 180,000 40,000 120,000 120,000	19,000	Byproduct nickel-cobalt sulfide or hydroxide.
2016	Zimbabwe (Midlands)	Hunters Road Bindura Nickel Corp. [Mwana Africa Holdings (Pty) Ltd.]	0.55	36,000	2,000	Concentrate.

Do. Ditto. NA Not available.

<sup>1</sup>Two years are shown for selected newly commissioned projects where the company is ramping up production.

<sup>2</sup>Company names reflect organizational structure as of January 31, 2012. 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.

<sup>3</sup>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.

<sup>4</sup>The Sinclair deposit remains open at depth.

<sup>5</sup>Includes Diggers Rocks, Diggers South, Purple Haze, and Seagull resources.

<sup>6</sup>Diggers areas, probable ore reserves.

<sup>7</sup>Cosmic Boy area, indicated resources.

<sup>8</sup>Diggers areas, indicated resources.

<sup>9</sup>Altona Mining Ltd. was created when Universal Resources Ltd. merged with Vulcan Resources Ltd. in February 2010.

<sup>10</sup>Jilin Jien Nickel Industry Co., Ltd. and Goldbrook Ventures Inc. completed their acquisition of Canadian Royalties Inc. on January 12, 2010.

<sup>11</sup>Mustang Minerals Corp. was also evaluating the potential of resources at the nearby Mayville property.

<sup>12</sup>Massive sulfides.

<sup>13</sup>Disseminated sulfides.

<sup>14</sup>Aquarius Platinum Ltd. acquired Ridge Mining plc in July 2009 and took over management of Sheba's Ridge in August 2009.

<sup>15</sup>Nokomis deposit indicated resource.

<sup>16</sup>Nokomis deposit inferred resource.

<sup>17</sup>In March 2011, Twin Metals Minnesota LLC (TMM) acquired Franconia Minerals Corp., doubling the project's mineral and land assets.

<sup>18</sup>Birch Lake deposit indicated resource.

TABLE 14—Continued  
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAREND 2016

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<sup>19</sup>Birch Lake deposit inferred resource.

<sup>20</sup>Maturi deposit resource.

<sup>21</sup>Spruce Road open pit resource.

Sources: Canadian Minerals Yearbook 2008, 2009; company annual reports, presentations, and press releases; CRU International, Ltd., and the International Nickel Study Group.