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# 2006 Minerals Yearbook

## NICKEL

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

July 2008

# NICKEL

By Peter H. Kuck

**Domestic survey data and tables were prepared by Barbara J. McNair and Linda M. White, statistical assistants. The world production tables were prepared by Glenn J. Wallace, international data coordinator.**

Acquisitions and mergers have changed the structure of the global nickel industry since 2004. In 2006, Falconbridge Limited and Inco Limited—the two leading nickel producers in Canada—were taken over by even larger mining companies. MMC Norilsk Nickel Group (Russia), the leading nickel producer in the world, launched a series of takeovers that gave the company footholds in mine development programs and production operations in Australia, the European Union (EU), North America, and southern Africa.

In 2006, stainless steel accounted for more than 60% of primary nickel consumption in the world (Nickel Institute, 2007). However, in the United States, this percentage was only 51% because of the relatively large number of specialty metal industries and readily available stocks of stainless steel scrap. Cupronickel alloys, high-temperature nickel-chromium alloys, naval brasses, superalloys and related aerospace alloys, and surface finishes are some of these specialty materials. Nickel metal foam is increasingly being used in the manufacture of rechargeable batteries.

Largely fueled by increased use of stainless steel worldwide and strong economic growth in China, growth of global nickel consumption has averaged 3.4% per year since 2001. World use of stainless steel weakened during the second half of 2005 but resumed its upward movement in early 2006 (International Nickel Study Group, 2007, p. 3-7). Consumption of nickel in batteries has grown dramatically since 1995 but still accounts for less than 5% of world nickel consumption. The world nickel-producing industry was operating at close to capacity in 2006, although a few producers experienced disruptions in production owing to feed material shortages, inclement weather, and labor problems.

## Legislation and Government Programs

***New U.S. Coinage.***—As part of the 50 State Quarters™ Program, the U.S. Mint produced 2.93 billion commemorative quarters in 2006, down from 3.01 billion in 2005. A total of 29.64 billion of the cupronickel clad coins was minted between December 1998 and December 2006. Between 34 billion and 37 billion quarters will have been minted when the program ends in December 2008, down from previous forecasts. Each coin weighs 5.67 grams (g) and contains 8.33% nickel, and thus 1,380 metric tons (t) of nickel was used in the five commemoratives released in 2006 (U.S. Mint, undated a, b).

The U.S. Mint began releasing the golden-colored Sacagawea dollar coin in January 2000 and by yearend 2005 had struck 1.46 billion of the manganese brass-clad coins. An additional 7.7 million were made in 2006, excluding San Francisco proofs. The dollar coin contains 2.0% nickel and weighs 8.1 g. The U.S. Mint began modifying the Jefferson nickel (5-cent coin) in late 2003 to commemorate the Lewis and Clark Expedition bicentennial (Public Law 108-15), but returned to the 1938 Monticello reverse design in 2006. The 2006 obverse bears a redesigned image of Thomas Jefferson. Each coin weighs 5.0 g and is made of solid cupronickel with a nickel content of 25%. The Mint produced 1.50 billion of the redesigned Jefferson nickels in 2006 (U.S. Mint, undated b, c).

## Exploration and Development

***Alaska.***—Several companies were actively exploring for copper, nickel, and platinum-group elements (PGEs) in southern Alaska. In April, Pacific North West Capital Corp. acquired a lode exploration and mining lease in the Goodnews Bay area from Calista Corporation. Calista, one of the 13 Alaskan Native Corporations created in 1971, controls more than 26,000 square kilometers ($km^2$) in the Yukon-Kuskokwim River Delta and the Kuskokwim Mountains. Exploration initially focused on Red Mountain and nearby Susie Mountain, which are two zoned ultramafic intrusives with dunite cores (Van der Poel and Hinderman, 2000, p. 1-9; Pacific North West Capital Corp., 2006; 2007).

***Michigan.***—In February, Kennecott Minerals Company (a member of The Rio Tinto Group) submitted a mining permit application to the Michigan Department of Environmental Quality to mine the relatively small but high-grade Eagle copper-nickel deposit on the Upper Peninsula. Kennecott geologists estimated that the deposit, located in Marquette County, contained 4 million metric tons (Mt) of sulfide ore grading 3.6% nickel and 3.1% copper (Jackman, 2005). The proposed operation would be the only primary nickel mine in the United States.

***Minnesota.***—PolyMet Mining Corp. of Vancouver, British Columbia, Canada, sought final regulatory approval to develop the NorthMet project—a copper-nickel-PGE deposit in northeastern Minnesota. In early 2006, Polymet decided to complete its definitive feasibility study on the basis of a 32,000-metric-ton-per-day (t/d) production rate instead of the original 25,000-t/d rate. The ore would be shipped to the former Cliffs Erie mill near the town of Hoyt Lakes for crushing, grinding, and subsequent flotation. In September, Bateman Engineering (Pty) Ltd. submitted a positive definitive feasibility study on the mining and processing project. The proposed facility would produce 33,000 metric tons per year (t/yr) of copper cathode, 7,000 t/yr of nickel in hydroxide, 330 t/yr of cobalt in hydroxide, and 3.4 t/yr (110,000 troy ounces per year) of contained gold and PGE in a precious metals precipitate. The project could be operational by early 2009 (PolyMet Mining Corp., 2006a, b; undated).

In October, Duluth Metals Ltd. (Toronto, Ontario, Canada) was spun off from Wallbridge Mining Company Ltd. after the initial public offering of Duluth Metals was successfully completed. Duluth Metals took over Wallbridge's exploration and development programs in the Duluth Complex. The new company was focusing its efforts on the Maturi Extension property, a copper-nickel-PGE deposit located northeast of NorthMet with similar mineralogy. Franconia Minerals Corp. (Spokane, WA) was considering developing neighboring deposits at Birch Lake and Maturi (Duluth Metals Limited, 2007).

## Production

***Byproduct Production.***—The United States had no active nickel mines in 2006. Except for limited quantities of byproduct nickel that were recovered at some copper and precious metal refineries, imports or recycling met all needs. In 2006, Stillwater Mining Company (majority owned by Norilsk Nickel) shipped 737 t of nickel in crystalline sulfate. The company mined PGE ore in Montana's Beartooth Mountains. The company's two mills (East Boulder and Nye) together processed 1.23 Mt of ore and subgrade material in 2006, with a combined mill head grade of 17 grams per metric ton (g/t) palladium and platinum. Concentrates from the two mills were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing 50% to 55% PGE by weight was produced. The crystalline nickel sulfate is a refinery byproduct and contains minor amounts of cobalt (Stillwater Mining Company, 2007a, p. 1-8; b, p. 13-18, 40).

Asarco LLC (a wholly owned subsidiary of Grupo México, S.A. de C.V.) produced minimal amounts of byproduct nickel sulfate at its Amarillo, TX, copper refinery in 2006. In 2004, Phelps Dodge Corp. (Phoenix, AZ) had begun producing byproduct nickel carbonate from a new circuit at its El Paso, TX, copper refinery. The El Paso refinery had been in almost continuous operation since 1931 and produced limited amounts of byproduct nickel sulfate from the old circuitry before it was replaced. In March 2007, Freeport-McMoRan Copper & Gold Inc. acquired Phelps Dodge for $26 billion.

Limited tonnages of primary nickel were recovered during the refining of some crude oils where the element occurs in porphyrins or other organometallic compounds. The nickel content of crude oil is quite variable and reflects several factors, such as the density of the oil, the sulfur content of the oil, the field location, geologic occurrence, and geologic age. The nickel is concentrated in flexicoke and other petroleum refinery residues; in fly ash, ash sludge, slags, and boiler scale produced at oil-fired powerplants; and in spent petroleum refinery catalysts.

***Secondary Production.***—International Metals Reclamation Company Inc. (a subsidiary of Vale Inco Limited) continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. Feed materials included chromium and nickel wastes generated by the stainless steel industry; filter cakes, solutions, and sludges from the plating industry; refractory brick; spent catalysts; and spent nickel-base batteries.

Extraction of nickel from catalysts is complex and has not been economic in some situations. Gulf Chemical and Metallurgical Corp. of Freeport, TX, which is owned by the Eramet Group (France), was one of a limited number of companies worldwide that processed spent catalysts from petroleum refineries in 2006. The Freeport facility can treat nickel/molybdenum and cobalt/molybdenum hydrotreating catalysts that have been "poisoned" by nickel and vanadium in the porphyrin molecules of crude oil. Gulf Chemical converts the byproduct nickel residue to a crude nickel-cobalt alloy in an electric furnace, and then sells the alloy to nickel refineries.

## Consumption

In 2006, world use of primary nickel was reported to be 1.40 Mt, an alltime high and a 12% increase compared with the 1.25 Mt consumed in 2005 (International Nickel Study Group, 2007, p. 3). Most nickel producers continued to operate at full capacity. Demand was buoyed by spiraling apparent consumption in China, which had risen to 261,000 t in 2006 from 43,400 t in 1999. The steel industry in the EU was the leading consumer of primary nickel (317,000 t) followed by China (155,000 t) and Japan (124,000 t) (Eramet Group, 2007, p. 55).

U.S. apparent consumption of primary nickel was 144,000 t, or about 10% of world consumption. U.S. industry reported consumption of an additional 108,000 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels increased to 53% in 2006 from 45% (revised) in 2005.

U.S. demand for most nonferrous alloys continued to strengthen. Markets for copper-nickel alloys were especially hard hit in 2003 but had recovered significantly by 2006. Consumption of superalloys—key fabrication materials for jet engines—increased by 14% (in terms of nickel content) compared with that of 2005. For the third year in a row, U.S. aerospace sales increased in every sector of the industry except for military aircraft sales, which decreased slightly from 2005 to 2006 (Blakey, 2007).

The estimated value of apparent primary nickel consumption in the United States was $3.49 billion, up from $1.99 billion (revised) in 2005. Apparent primary consumption increased by 6% from 135,000 t (revised). The sharp increase in the value of primary consumption resulted from the combined effect of a 64% increase in the London Metal Exchange (LME) cash price and a moderate increase in primary consumption. Apparent primary consumption plus reported secondary consumption totaled 252,000 t (table 1).

***Stainless Steel and Low-Alloy Steels.***—In 2006, stainless steel producers accounted for 50% of primary nickel consumption in the United States (table 4) and more than 60% of primary consumption in the world. Production of raw stainless steel (excluding production in China, the Commonwealth of Independent States, and Eastern Europe) has been increasing at a compound annual growth rate of 5.7% since 1950. Production grew to 23.0 Mt in 2006 from 14.9 Mt in 1996 (Vale Inco Limited, 2007, p. 4). According to the International Stainless Steel Forum, world stainless steel production rose by

16.7% to 28.4 Mt in 2006 from 24.3 Mt in 2005 (International Iron and Steel Institute, 2007).

In 2006, use of stainless steel in the Western World resumed its upward trend, reaching an alltime high of 16.3 Mt. The increase followed a 2.7% decline (revised) in use between 2004 and 2005, when global production temporarily outpaced consumption despite the demand in China. Because of this imbalance, significant destocking took place in the EU and the United States during 2005. The stainless steel industry in the Western World experienced a compound annual growth rate of 4.4% from 1996 to 2006. A large part of the growth was in India, the Republic of Korea, and Taiwan, where additional melt capacity was being brought onstream to accommodate the projected growth in demand for stainless steel after 2008. There also has been a worldwide shift to increasingly larger meltshops; seven stainless steel companies now operate meltshops with capacities larger than 900,000 t/yr (Vale Inco Limited, 2007, p. 16-24).

Since 2001, China has consumed more stainless steel annually than any other country. China consumed 6.35 Mt of stainless steel in 2006. China's steel industry produced 5.32 Mt of crude stainless steel in 2006, 67% more than in 2005. Chinese imports of stainless steel totaled 2.50 Mt; exports, 0.90 Mt (Vale Inco Limited, 2007, p. 17-18, A-37–A-38).

Production of raw stainless steel and heat-resisting steel in the United States totaled 2.46 Mt in 2006—the highest annual production ever recorded for the United States. Nickel-bearing grades accounted for 1.71 Mt, or 70% of total stainless steel production—also an alltime record (American Iron and Steel Institute, 2007a, p. 70-75; b). The meltshop of North American Stainless (NAS) in Ghent, KY, produced 850,000 t of stainless steel slabs—11% more than that of 2005. NAS commissioned its No. 2 electric furnace in the last quarter of 2006 and ordered a second argon-oxygen decarburization (AOD) converter shortly thereafter. The new equipment will raise the capacity of the meltshop to 1.42 million tons per year (Mt/yr), making it the leading shop in North America beginning in 2009 (Acerinox, S.A., 2007, p. 12, 104-107).

***Superalloys and Related Nickel-Base Alloys.***—Of the primary nickel consumed in the United States, approximately 16% was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of superalloys increased by14% from that of 2005 owing to increased sales to manufacturers of jet aircraft engines and other sectors of the aerospace industry.

In May, Precision Castparts Corp. (PCC) of Portland, OR, completed the acquisition of Special Metals Corporation (SMC), a leading producer of high-performance nickel-base alloys and superalloys headquartered in New Hartford, NY. The total purchase price was approximately $553 million in cash. PCC specialized in manufacturing large, complex structural investment castings, airfoil castings, and forged components used in jet aircraft engines and industrial gas turbines. SMC provided PCC an internal supply of nickel-base billets for its forging operations (Precision Castparts Corp., 2006, p. 23, 67).

In July, Allegheny Technologies Inc. (ATI) commissioned two electroslag remelt (ESR) furnaces at its Latrobe, PA, facility. The two furnaces will be used to expand the company's premium-melt nickel-base alloy, superalloy, and specialty alloy capabilities. In January 2007, ATI announced that it had signed a long-term sourcing agreement with General Electric Aviation to supply nickel-base superalloys for commercial and military jet engines. The agreement could generate more than $2 billion in revenue for ATI from 2007 through 2011 (Allegheny Technologies Inc., 2007, p. 4-10). In May 2005, ATI began distributing technical data sheets for Allvac 718Plus, a new patented nickel-base superalloy, to manufacturers of gas turbines. The new alloy closes the gap between traditional alloys 718 and Waspaloy; the new alloy allows the turbine to operate at a service temperature of up to 650° C, which is about 55° C higher than in the past and results in improved fuel efficiency (Kennedy and McDevitt, 2008).

***Nickel-Base Batteries and Hybrid Electric Vehicles.***—U.S. demand for nickel in rechargeable batteries continued to increase. In 2006, most of the newer hybrid electric vehicles (HEVs) on U.S. highways were using nickel-metal hydride (NiMH) batteries to store the energy recovered from the vehicle's regenerative braking circuitry—a system that reduces overall fuel consumption. Most battery manufacturers were using either pasted foam or sintered electrodes in NiMH cell production. Toyota Motor Corp. continued to rely on NiMH technology and postponed plans to switch to lithium-ion batteries in its next-generation Prius, a popular hybrid hatchback (Shirouzu, 2007).

Growing HEV sales in East Asia and North America increased demand for nickel foam and specialty nickel metal powders, key NiMH battery components. In the United States, sales of gasoline-electric hybrid vehicles continued to rise, but the rate of growth had begun to slow. Nationwide registrations of new hybrid vehicles rose to 254,545 in 2006, 28% greater than 199,148 in 2005 (R.L. Polk & Co., 2007). Toyota produced more than 1,047,000 HEVs worldwide between 1997 and May 2007, and was expanding capacity at its plants in Japan to 300,000 vehicles per year (Hybrid & Electric Vehicle Progress, 2007). In October 2006, Toyota began production of the Camry hybrid car at Georgetown, KY—the first hybrid produced in North America by the world's leading HEV manufacturer. The Georgetown plant produced 4,249 Camry hybrid cars in the fourth quarter of 2006. Ford Motor Co. and Honda Motor Co. were also manufacturing HEVs powered in part by conventional NiMH batteries (Alford, 2006).

## Stocks

On December 31, 2006, stocks in London Metal Exchange (LME) warehouses worldwide totaled 6,594 t and were 9% greater than the 6,066 t in stock on November 30. The 2006 yearend figure, however, was extremely low in comparison to the equivalent figures for 2003, 2004, and 2005. LME stock levels were low throughout the second half of 2006 owing to growing demand for austenitic stainless steel in Asia (International Nickel Study Group, 2007, p. 4, 6). On July 31, stocks bottomed out at 4,158 t, the lowest end-of-month figure reported in at least 12 years. Data collected by the International Nickel Study Group indicated that, at yearend 2006, world

nickel producers (excluding those in Austria, China, Macedonia, Serbia, and the Ural region of Russia) had approximately 89,000 t of primary nickel stocks. About 73%, or 65,400 t, of the producer material was Class I material (refined products with a nickel content of 99% or greater), which included, in order of decreasing production, electrolytic cathode, briquets, pellets, powder, rondelles, and so forth. The remaining 27% 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 are Class I (International Nickel Study Group, 2007). In comparison, on December 31, U.S. consumer stocks of primary nickel totaled 7,160 t, which was 7% more than the 6,670 t (revised) in stock at yearend 2005.

## Prices

The January 2006 average cash price for 99.8% pure metal on the LME was $14,550 per metric ton ($6.600 per pound)—a relatively high price in historical terms. Nickel prices began strengthening in April. The monthly average for May was $21,065 per ton ($9.555 per pound), surpassing the alltime high of $18,524 per ton ($8.402 per pound) reached in February 1989. Prices climbed even further during the second half of 2006. The average LME cash price for December was $34,559 per metric ton ($15.676 per pound), a record high to that point in time. The average annual price was $24,244 per ton ($10.997 per pound)—64% greater than the 2005 average (as published in Platts Metals Week).

Société Générale CIB, an investment bank, warned that the physical nickel market was not as tight as escalating prices and dwindling visible stocks suggested. The bank, however, was quick to point out that increasing global production of stainless steel, especially in China, had created a temporary supply deficit. Startup delays at Goro (New Caledonia), Ravensthorpe (Australia), and other key mining projects helped prolong the deficit. Some analysts predicted that nickel prices could remain high for some time, assuming institutional investors remained in the LME nickel futures market. Market consolidation following the Falconbridge and Inco Limited (Inco) takeovers could also influence long-term prices (Bhar, 2006; Platts Metals Week, 2006b).

## World Industry Structure

At the beginning of 2006, the world's leading nickel producer was Norilsk Nickel, followed by Inco (Canada). Other major producers were BHP Billiton Group (United Kingdom), Eramet Group (France), and Falconbridge (Canada). Three major developments during the year, however, triggered several acquisitions and mergers that continued into 2007 and drastically changed corporate ownership of the nickel industry (McNish, 2006). BHP Billiton had become the third ranked producer of nickel in the world after it acquired WMC Resources Ltd. (Australia) in 2005.

***Creation of CVRD Inco (renamed Vale Inco in November 2007).***—On August 11, 2006, Companhia Vale do Rio Doce (CVRD) of Rio de Janeiro, Brazil, offered to purchase all the outstanding common shares of Inco for cash. CVRD offered Can$86.00 per share (US$76.74)—a bid valued at US$17.6 billion (Samor, Heinzl, and Berman, 2006). On October 19, the Canadian Minister of Industry formally approved CVRD's proposal to acquire Inco. The "net benefit to Canada" ruling allowed CVRD to complete its all-cash offer. CVRD already had obtained approval from regulatory authorities in the EU and the United States. On October 24, CVRD announced that it had acquired 75.66% of Inco's outstanding common shares for US$13.3 billion and was taking control of the Toronto-based nickel producer. Inco was renamed CVRD Inco Limited and was given management responsibility for CVRD's Onca Puma and Vermelho nickel projects in Brazil. As part of an agreement with the Government of Canada, CVRD Inco's global nickel business was to be based in Toronto. CVRD Inco was to initiate new discussions with the Government of Newfoundland and Labrador and to seek approval to accelerate the second phase of the Voisey's Bay Project (Companhia Vale do Rio Doce, 2006a, b, c).

***Creation of Xstrata Nickel.***—In May 2006, Xstrata announced its intention to acquire Falconbridge. Xstrata already owned 19.8% of Falconbridge's outstanding common stock at the time and offered to buy the remaining shares for Can$52.50 cash per share (approximately US$47.42). The Swiss mining group subsequently raised its offer to Can$63.25 per share (approximately US$56.44). In August, Xstrata announced that it had increased its holdings to 67.8% and was taking control of the Canadian company. The acquisition was completed on November 1. Falconbridge, renamed Xstrata Nickel, became a commodity business unit within the Swiss group but remained headquartered in Toronto (Falconbridge Limited, 2006; Xstrata plc, 2006).

***Norilsk Nickel Acquisition of Assets in the Southern Hemisphere.***—In November, OM Group Inc. (OMG) agreed to sell all its nickel assets to Norilsk Nickel for $408 million in cash. The assets included OMG's refining operations in Harjavalta, Finland; OMG's Cawse mining and leaching operations in Western Australia; and OMG's 20% interest in MPI Nickel Pty. Ltd. of Australia. MPI Nickel operated the Black Swan and Silver Swan Mines, 45 kilometers (km) northeast of Kalgoorlie. Norilsk Nickel also would be allowed to acquire part of OMG's holdings in Talvivaaran Kaivososakeyhtiö, a biological heap-leaching project in the Kainuu district of Finland. At yearend, Norilsk Nickel and OMG needed approval from regulatory authorities in Australia and the EU before the transaction could be settled (OM Group, Inc., 2006).

## World Review

***Australia.***—Australia was the third ranked nickel-producing country in the world. Most of the nickel properties under development were in the State of Western Australia. Key events of 2006 are summarized in the nickel section of the State's Mineral and Petroleum Statistics Digest (Government of Western Australia, 2007, p. 23-25) and in Volume III, Area Reports: International, of the U.S. Geological Survey Minerals Yearbook.

***Laterite Operations.***—Three nickel laterite mining and processing operations have been commissioned in the Kambalda-Goldfields region since 1998—Bulong, Cawse, and Murrin Murrin. However, only the Murrin Murrin Joint Venture near Leonora and OMG's intermediate carbonate plant at Cawse had significant commercial production in 2006. Murrin Murrin was the second ranked producer in Western Australia after BHP Billiton's Nickel West, and produced 31,524 t of nickel, up by 12% from 28,240 t produced in 2005. Murrin Murrin is a joint venture of Minara Resources Limited (60% interest) and Glenmurrin Pty. Limited [a subsidiary of Glencore International AG of Switzerland (40%)]. Mining studies were underway to determine if it was commercially feasible to truck ore from the Irwin Hills/Coglia Well District to Murrin Murrin. The Irwin Hills project (a joint venture with Yilgarn Mining Ltd.) had 17.9 Mt of resources averaging 1.07% nickel at a 0.8% nickel cutoff grade (Minara Resources Limited, 2007, p. 2-14, 28).

Cost overruns at BHP Billiton's Ravensthorpe project in Western Australia increased the total capital cost to $2.2 billion from the $1.4 billion originally budgeted for in 2004. Because of late delivery of materials and equipment, the first output from the project was rescheduled to reach the Yabulu refinery in Queensland in early 2008. Overall construction at Ravensthorpe was 78% complete at the end of 2006. The expansion of the Yabulu refinery was completed, raising the capacity of the facility to 76,000 t/yr of nickel and 3,500 t/yr of cobalt (BHP Billiton Plc, 2006, p. 38, 93; 2007; Clark, 2007).

***Sulfide Operations—Western Australia.***—BHP Billiton created Nickel West in June 2005 to manage part of the assets acquired in the takeover of WMC. In fiscal year 2006, Nickel West produced 62,000 t of metal briquettes and powder at Kwinana from concentrates smelted at Kalgoorlie. The Kalgoorlie smelter also produced about 38,000 t of nickel in finished matte for export. About 38% of the concentrate came from the Mount Keith Mine in the Northern Goldfields region. The other 62% came from Leinster and third party mines at Kambalda (Wilson, 2006). Nickel West was in the process of expanding its Mount Keith operation and was preparing to commission its new 11 Mile Well open pit. Mount Keith had an estimated 213 Mt (dry) of proven and probable ore reserves averaging 0.54% nickel plus 140 Mt (dry) of additional resources averaging 0.50% nickel. Nickel West was reevaluating the undeveloped Yakabindie deposit, 25 km south of Mount Keith. Geologists estimated that the low-grade deposit had 248 Mt (dry) of indicated resources averaging 0.57% nickel (BHP Billiton Plc, 2006, p. 74-75).

In fiscal year 2006, LionOre Mining International Ltd. produced 9,737 t of nickel in concentrates from its Emily Ann and Maggie Hays Mines in the Lake Johnston area. LionOre began shifting its efforts from Emily Ann to Maggie Hays to compensate for Emily Ann's declining reserves. Maggie Hays, a new mine that began production in the fourth quarter of 2004, is located 3 km south of Emily Ann. Ores from both mines were being processed through the same 500,000-t/yr sulfide flotation plant. According to LionOre officials, at yearend 2006, Emily Ann had 70,000 t of reserves averaging 2.66% nickel, and Maggie Hays had 3,420,000 t of reserves averaging 1.42% nickel and at least 6.1 Mt of other indicated resources averaging 1.71% nickel. The entire area is part of the Lake Johnston Greenstone Belt and has several promising gold exploration targets in addition to the nickel deposits (LionOre Mining International Ltd., 2007, p. 10-16, 31).

***Sulfide Operations.—Tasmania.***—Jinchuan Group Limited, the leading nickel producer in China, agreed to buy 70,000 t of nickel in sulfide concentrates from Allegiance Mining NL during the next 8 to 10 years. The concentrates were to come from Allegiance's new Avebury Mine near Zeehan, in the West Coast Region of Tasmania, which began producing in December. Jinchuan was to loan Allegiance $3.7 million to accelerate mine development. The nearly completed concentrating complex was scheduled to be commissioned in late 2007 and was expected to produce about 8,500 t/yr of contained nickel (Allegiance Mining NL, 2007, p. 1-13).

***Botswana.***—In August, the Government of Botswana approved LionOre's request to build a $620 million base-metals refining complex at the Tati Mine. LionOre had been developing Tati for the past 9 years. The Activox® refinery was expected to cost $482 million; the dense media separation plant, $114 million. LionOre would have an 85% interest in the complex; the Government, 15% (LionOre Mining International Ltd., 2007, p. 1, 6-7, 24-25).

***Brazil.***—In January 2006, CVRD awarded the management contract for its Vermelho project in the State of Para to GRD Minproc (Pty) Ltd., the engineering construction subsidiary of Australia's GRD Limited. Two Brazilian engineering companies, Minerconsult Engenharia and Setal Engenharia Construções e Perfurações, were providing support to GRD Minproc (Companhia Vale do Rio Doce, 2005b; GRD Limited, 2008, p. 14). In December 2005, CVRD acquired Canico Resource Corp. (Toronto, Ontario, Canada) for about Can$57 million (US$49 million) to gain control of the Onca Puma laterite project in Para. Five months earlier, Canico completed a positive feasibility study of Onca Puma. The 2005 study called for the construction of an onsite smelter capable of producing 57,000 t/yr of nickel in ferronickel. Development was expected to cost $1.1 billion. The nickel deposit has 104 Mt of resources averaging 2.15% nickel (Companhia Vale do Rio Doce, 2005a; Reuters Limited, 2005).

In December 2006, GrupoVotorantim announced that it was expanding its processing capacity in the State of Goias. The company planned to build a new ferronickel plant near its leaching operations at Acampamento Macedo on the outskirts of Niquelandia. The plant would be capable of producing 10,600 t/yr of nickel in ferronickel and would begin production in 2009. Ore for the plant would come from the company's existing nickel mine operated by subsidiary Cia. Niquel Tocantins. The ferronickel would be produced for the export market (Votorantim Metais, 2007).

Following a feasibility study completed in September 2006, Anglo American plc approved development of the Barro Alto ferronickel plant, also located in the State of Goias. Construction of the $1.2 billion complex was scheduled to begin in 2007, with production starting in 2010. The plant is designed to produce 36,000 t/yr of nickel in ferronickel. The Barro Alto laterite deposit, acquired from Inco in 2002, has 116 Mt of resources grading 1.54% nickel. Anglo American was shipping ore from

Barro Alto to the ferronickel plant of its subsidiary Codemin S.A. in Niquelandia, a distance of 150 km (Platts Metals Week, 2006a).

***Canada.***—Key events of 2006 are summarized in the nickel chapter of the Canadian Minerals Yearbook (Bill McCutcheon, senior commodity advisor, Natural Resources Canada, written commun., 2007; 2008; unpub. data, 2007).

***Alberta.***—In December 2005, Gulf Chemical announced that it would build a full-service spent catalyst processing facility at Fort Saskatchewan, Alberta, Canada. The $36 million state-of-the-art facility was being located in Alberta to support growing oil production from the Province's abundant tar sands. The bitumen in the tar sands contains significant organonickel and organovanadium compounds (Gulf Chemical & Metallurgical Corp., 2005; Eramet Group, 2006, p. 26).

***Manitoba and Nunavut.***—CVRD Inco's operations at Thompson produced 35,300 t of refined nickel in 2006 from ores extracted from the Birchtree and Thompson Mines. Declining production in the Thompson Nickel Belt was offset by imports of nickel concentrate from Australia and CVRD Inco's new mill at Voisey's Bay, Labrador (Inco Limited, 2006b, p. 19-25; McCutcheon, 2005; 2007).

At yearend 2006, Crowflight Minerals Inc. asked Micon International Ltd. to assist in updating its feasibility study of the Bucko Lake project near Wabowden. In late 2006, Crowflight purchased the Chimo concentrator near Louvicort, Quebec, and was in the process of dismantling and transporting the equipment to the Bucko mine site for erection. The proposed underground mine at Bucko Lake would produce 5,700 t/yr of nickel in sulfide concentrate (Beauchamp and others, 2007, p. 1-4).

***Ontario.***—Several exploration projects were underway, particularly in and around some older, largely depleted mines in the Sudbury District. CVRD Inco's Ontario Division was the leading nickel producer in the district. The division's milling operations produced about 98,000 t of nickel in concentrates in 2006, some of which came from tolled ores (Inco Limited, 2006a, p. 1-16; 2006b, p. 25; McCutcheon, 2007). CVRD Inco reported that 93,000 t of refined nickel was produced by the division in 2006, of which 37,000 t was recovered at the division's Clydach refinery in the United Kingdom. Production figures for the division may be not comparable with those of past years because of changes in reporting methodology following the takeover of Inco (McCutcheon, 2007). Falconbridge, Sudbury's other principal producer, mined 1.89 Mt of ore with an average grade of 1.11% nickel and 1.20% copper (Xstrata plc, 2008, p. 5). FNX Mining Company Inc. continued to extract ore from the reopened McCreedy West Mine and had put the adjoining gold and PGE-rich "PM Deposit" into commercial production. FNX delivered 625,000 t of ore in 2006 to CVRD Inco's Clarabelle Mill. The shipments included 310,000 t of nickel ore, which yielded 3,700 t of payable nickel (FNX Mining Company Inc., 2007, p. 1-5, 21).

Falconbridge's new Montcalm Mine near Timmins mined 876,000 t of ore that averaged 1.50% nickel and treated 891,000 t at the company's Kidd mill, where 10,900 t of nickel in concentrate was recovered (Xstrata plc, 2008). In March 2007, Xstrata published updated information on Falconbridge's Canadian ore reserves and other resources (Xstrata plc, 2007b).

***Quebec.***—More than 20 companies are actively exploring for copper, nickel, and PGEs in the Nunavik region of northern Quebec. In 2006, the Raglan Mine, which became part of Xstrata on November 1, produced 23,704 t of nickel in concentrate, which is 3% more than the 22,917 t recovered in 2005 (Xstrata plc, 2008).

In July, Canadian Royalties Inc. received a scoping study of its Raglan South nickel project from P&E Mining Consultants Inc. and began expanding its exploration drilling program. In August, the Sullivan-based company awarded a contract for a bankable engineering feasibility study to SNC-Lavalin. The feasibility study was to be based on a 3,500-t/d milling operation. Genivar Consulting Group Ltd. won the contract for the environmental and social impact assessment. By yearend 2006, Canadian Royalties had identified 16.2 Mt of indicated resources averaging 0.91% nickel and 1.1% copper (Canadian Royalties Inc., 2007, p. 1, 7, 9-11).

***China.***—Chinese demand for primary forms of nickel continued to escalate and was estimated to have reached 257,000 t in 2006, which was 37% greater than that of 2005 (Eramet Group, 2007, p. 55). The Chinese stainless steel industry currently accounts for about 60% of the country's primary nickel consumption. China was the world's leading stainless-steel-producing country in 2006, with a crude stainless steel output of 5.32 Mt. Chinese production of stainless steel has been growing at an average annual rate of 31% since 1996. Taiyuan Iron & Steel (Group) Company Ltd. (TISCO) and the Baosteel Group accounted for more than 40% of the country's stainless steel meltshop production (Vale Inco Limited, 2007, p. 4, 17-18). At least three new melt facilities of private enterprises were commissioned in 2006. China was the world's leading consumer of stainless steel in 2006, accounting for at least 27% of world stainless steel consumption, which is 9% more than the total consumption of Western Europe.

China has a large electroplating industry and a number of rechargeable battery manufacturers that use nickel. China's plating industry accounted for about 19% of the country's primary nickel demand in 2006 (Eramet Group, 2007, p. 55).

In May, Inco announced plans to build a plant at Dalian in Liaoning Province that would produce Utility® nickel for China's rapidly growing stainless steel industry. Construction of the $63 million facility reportedly began in the third quarter of 2006. The new nickel plant would have a capacity of 32,000 t/yr and use nickel hydroxide feed from CVRD Inco's Goro project in New Caledonia. POSCO E&C (Beijing) Co. Ltd. was to be responsible for part of the engineering and construction work. Korea Nickel Corp., CVRD Inco's subsidiary at Onsan, Republic of Korea, would provide the technology and related technical support.

At the beginning of 2006, China began producing a low grade of ferronickel, which industry analysts refer to as nickel pig iron (NPI). NPI was being offered in China as an alternative to stainless steel scrap. The first NPI was made from low-grade unprocessed laterite ore imported from the Philippines. In late 2006, however, higher grades of ore imported from Indonesia

became increasingly popular. The appearance of NPI was attributed to high nickel prices and spot shortages of scrap.

***Cuba.***—In 2005, Grupo Empresarial del Níquel (Cubaniquel) and its Canadian partner, Sherritt International Corporation, began upgrading and expanding the capacity of the Pedro Soto Alba mining and processing complex at Moa. The capacity of the acid leaching operation was to be raised eventually to 49,000 t/yr of nickel plus cobalt in a mixed sulfide precipitate from 33,000 t/yr. A parallel expansion was being carried out at the joint venture's downstream refinery in Fort Saskatchewan, Alberta, Canada. In 2006, the Fort Saskatchewan refinery produced 30,212 t of nickel and 3,312 t of cobalt. About 95% of the feed came from Moa. The first phase of the expansion was on schedule and was to have been completed by yearend 2007, increasing capacity initially by 4,000 t/yr of mixed metal. The second phase, scheduled for completion in 2009, would increase capacity an additional 9,000 t/yr (Sherritt International Corporation, 2007, p. 5-7).

***Guatemala.***—Elevated nickel prices have made development of several nickel-cobalt laterite deposits in the Ophiolitic/Laterite Belt of Guatemala more attractive. Plans were drawn up to reopen the long closed nickel mines of Exploraciones y Explotaciones Izabal, S.A. (EXMIBAL), a defunct Inco subsidiary. At the end of 1980, Inco mothballed EXMIBAL's mining and processing facilities near the town of El Estor on Lake Izabal. Inco was forced to halt nickel production in November 1980 because of substantial increases in the price of fuel oil and low nickel prices. The integrated mining and smelting complex had been in operation for only 2 years. The complex originally cost $238 million and was designed to produce 11,300 t/yr of nickel in a 75% nickel sulfide matte. In 2004, Skye Resources Inc. (Vancouver, British Columbia, Canada) conditionally acquired a 70% interest in Compañía Guatemalteca de Níquel (CGN) from Inco. CGN holds title to the former Inco pyrometallurgical plant, together with valuable exploration and exploitation licenses in eastern Guatemala. Skye completed its purchase of CGN in March 2007 and owned 92.4% of the company. The remaining 7.6% was held by the Government of Guatemala. Skye was considering renovating the mothballed plant and transforming it into a state-of-the-art, energy-efficient facility for producing ferronickel. Startup costs would be minimal because Inco had maintained the complex during the 26-year period. In October 2006, Hatch Ltd. and other consultants completed a feasibility study for Skye. The proposed Fenix project would produce 22,000 t/yr of nickel in ferronickel from local laterites. BHP Billiton and CVRD Inco both hold significant positions in Skye (Skye Resources Inc., 2007, p. 2-4).

In 2001, Jaguar Nickel Inc. (formerly Chesbar Resources Inc.) began evaluating four nickel-cobalt concessions bordering Lake Izabal. Much of the work was done on the Sechol property, which adjoins Inco's mining and smelting complex. Jaguar also identified several promising deposits on the Marichaj and San Lucas properties, which are located to the northwest of Sechol. Together, the three properties form a boomerang-shaped zone of exploration targets covering 741 $km^2$. The Sechol area reportedly contains 37 Mt of resources averaging 1.4% nickel, 0.08% cobalt, and 12.6% magnesium oxide based on a cutoff grade of 1% nickel. The 37 Mt of resources includes 14 Mt of measured resources grading 1.46% nickel, 0.08% cobalt, and 13.85% magnesium oxide. The Sechol laterites differ somewhat from those in Brazil and Cuba. Much of the original magnetite remains in place and has not yet altered to limonite/goethite, opening the possibility of concentrating the nickel by wet magnetic separation. In February 2006, BHP Billiton Group acquired Jaguar's nickel holdings in Guatemala for Can$19 million in cash (approximately US$16 million) (Jaguar Nickel Inc., 2004; 2005).

***Indonesia.***—In May, Eramet bought Weda Bay Minerals Inc. (Toronto, Ontario, Canada) for Can$270 million in cash (approximately US$240 million). Weda Bay Minerals was the lead partner in a key laterite development project on Halmahera Island. The proposed $1.5 to $2.0 billion project would recover 60,000 t/yr of nickel from oxidized ores using a hydrometallurgical process being evaluated at Eramet's research center in Trappes, France. The Weda Bay group of deposits has 277 Mt of resources grading 1.49% nickel and 0.09% cobalt and is similar in size to Goro in New Caledonia (Bacardats, 2006).

***Korea, Republic of.***—Société Minière du Sud Pacifique S.A. (SMSP) (Noumea, New Caledonia) and POSCO (Seoul, Republic of Korea) agreed to construct a nickel refinery in the Gwangyang industrial area of the Republic of Korea. SMSP would provide feed for the plant from its laterite mines in New Caledonia, giving POSCO a secure source of nickel for its stainless steel operations. POSCO would provide financial support for upgrading and expanding SMSP's mining operations. The refinery would cost an estimated $350 million (Société Minière du Sud Pacifique S.A., 2008).

***New Caledonia.***—Inco's Goro project was scheduled to begin producing cobalt and nickel by late 2008. In April 2006, protests and sporadic acts of vandalism by local activists forced Inco to temporarily halt construction at Goro. The work stoppage had an immediate effect on LME nickel prices because of low stocks worldwide.

Work on the Koniambo ferronickel project was progressing near Kone in the Northern Province. Xstrata assumed Falconbridge's 49% interest in Koniambo. Société Minière du Sud Pacifique S.A. holds the remaining 51%. In December 2005, the Territorial government issued operating and construction permits for the $3.8 billion project. A month later, Falconbridge awarded a $250 million engineering and construction contract to Hatch and Technip S.A. The two companies were to develop construction plans for a smelter capable of producing 60,000 t/yr of nickel in ferronickel. The complex would have its own coal-fired powerplant to support the ore-transport facilities, the smelter, and associated infrastructure. Construction was scheduled to begin in 2008 with commissioning targeted for 2011 or 2012 (Xstrata plc, 2007a, p. 82-83).

***Russia.***—Norilsk Nickel was the leading producer of nickel in the world in 2006 and accounted for about 19% of world mine production. The company's operations on the Kola and Taimyr peninsulas had a combined output of 244,000 t of nickel—about 83% of Russia's primary nickel output for the year. Almost all the nickel was exported; only about 4,000 t, or less than 2%, was sold to Russian consumers (MMC Norilsk Nickel Group, 2007, p. 8-13, 52-60, 73-84, 166).

The remaining 17% of Russia's primary nickel output came from independent operations in the central and southern regions of the Ural Mountains—Rezh Nickel Works JSC (Sverdlovsk Oblast), Ufaleynikel JSC (Chelyabinsk Oblast), and OAO Mechel [formerly Yuzhuralnikel Combine JSC] (Orenburg Oblast).

Amur Minerals Corporation continued to focus on its Kun-Manie nickel-copper sulfide project in the Russian Far East. In October 2006, SRK Consulting launched an independent prefeasibility study of Kun-Manie to confirm that the project was economic based on the latest drilling data. The positive prefeasibility study was the first step needed to convert the company's exploration license to a 25-year mining license. Four ore bodies had been discovered thus far—Falcon, Ikenskoe, Maly Krumkon, and Vodorazdelny. Ikenskoe, Maly Krumkon, and Vodorazdelny have been drilled to a suitable spacing to permit resource estimation. Geologists estimate that these three ore bodies have 51 Mt of combined measured or indicated resources, averaging 0.49% nickel and 0.14% copper, plus 17 Mt of inferred resources of similar grade. Onsite crushing and flotation operations would generate 16,000 t/yr of nickel in concentrate (Amur Minerals Corporation, 2008, p. 5-9).

In January 2006, Norilsk Nickel and Rio Tinto established a Russian-registered joint-venture company, RioNor Exploration LLC. The new company, owned 51% by Norilsk Nickel and 49% by Rio Tinto, was to focus its efforts initially in the Siberian and Far-Eastern Federal Districts. The joint venture would be based in Russia and would pay local taxes and employ local staff (MMC Norilsk Nickel Group, 2006; 2007, p. 4, 12, 67).

***Tanzania.***—In February 2007, Xstrata Nickel announced that it was investing an additional $95 million to advance the Kabanga project. The project was a joint venture with Barrick Gold Corporation (Toronto, Ontario, Canada) (Barrick Gold Corporation, 2005). In 2005, Falconbridge (Xstrata Nickel's predecessor) had launched a $50 million exploration and developmental drilling program. In November 2006, Xstrata Nickel completed a scoping study begun by Falconbridge that raised Kabanga's inferred and indicated resources to 46 Mt grading 2.7% nickel. Three deposits had been identified—Main, North, and MNB. Project engineers proposed an underground mining operation with an onsite surface concentrator. If the final feasibility study is successful, the proposed operation could mine 2 Mt/yr of ore and produce 30,000 to 35,000 t/yr of nickel in sulfide concentrates. In December, Xstrata Nickel initiated a prefeasibility study (Xstrata plc, 2007a, p. 83).

***Zambia.***—Albidon Ltd. (West Perth, Australia) successfully completed a bankable feasibility study of its Munali nickel project. Work was focused on the Enterprise deposit at the southeastern corner of the Munali gabbroic intrusion, about 60 km south of Lusaka. In early 2006, Albidon reported that four drill holes designed to extend the northern and southern boundaries of the Enterprise deposit had intersected significant nickel mineralization. Drillhole data at the end of May indicated 6.7 Mt of probable ore reserves grading 1.23% nickel, 0.17% copper, 0.53 g/t palladium, and 0.23 g/t platinum. Construction of the underground mine and flotation concentrator began in September. The Munali Gabbro is one of at least five mafic intrusions being evaluated for sulfide mineralization in the more-than-2,000-km-long East Africa Nickel Belt. In December, Jinchuan Group Ltd. (Jinchuan City, Gansu Province, China) signed an offtake agreement with Albidon and agreed to provide $5 million in equity funding plus $20 million in subordinated debt (Albidon Limited, 2007, p. 4, 8-10).

## Outlook

With the exception of Kennecott's proposed underground mine in the Upper Peninsula of Michigan, no primary nickel producer is expected to be operating in the United States before 2020. Grupo México, Phelps Dodge (part of Freeport-McMoRan as of March 2007), and Stillwater will continue to recover limited amounts of byproduct nickel from precious metals and base-metals refining operations in the western United States. Larger amounts of byproduct nickel could also be generated in Minnesota if Duluth Metals, Franconia, PolyMet, and/or Teck Cominco Limited proceed with their PGE projects in the Duluth Gabbro. Increased byproduct nickel production from North American PGE operations could materialize if current forecasts for the production of fuel-cell-powered vehicles are accurate.

U.S. nickel consumers will apparently 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 Australia, Brazil, Cuba, Indonesia, New Caledonia, the Philippines, and Turkey will help meet the growing demand for nickel worldwide. Laterite projects are also under consideration in Côte d'Ivoire, Guatemala, and Kazakhstan. The nickel-cobalt hydroxide intermediate from Vale Inco's state-of-the-art leach facility at Goro will help meet the near-term growth in demand projected for nickel. The worldwide consolidation of nickel operations is expected to continue.

Rising prices for petroleum products have increased demand for hybrid vehicles and with it, NiMH batteries. The life and replacement cost of the different NiMH battery packs remain important issues (Williams, 2006). Since 1997, Toyota had sold more than 1 million hybrid vehicles worldwide.

North American demand for nickel- and cobalt-based superalloys was expected to escalate between 2008 and 2013, largely because of growing demand for new jet aircraft. The Boeing Co. and Airbus, which is owned by the European Aeronautic Defence & Space Co., won an impressive number of jet-aircraft orders in 2005 and 2006. Most of the orders, though, came from Asia and Europe. Boeing's new 787 Dreamliner, which uses improved engines and lighter-weight composite materials to save fuel, was not expected to be in full production until late 2008 (Wallace, 2006; Maxon, 2008).

In early 2007, nickel consumers, producers, and traders continued to be concerned about tight nickel supplies and record-high prices as the LME cash price outpaced forecasts made only 1 or 2 months earlier. Underlying market fundamentals remained strong, and hedge funds continued to buy into the market, even above the $30,000 per metric ton level. Some traders argued that nickel prices would remain high for an extended period of time; others cautioned that the market was becoming overly speculative and that nickel prices could turn downward quickly if institutional investors decided to exit

the LME nickel futures market (Markram, 2007; Metal Bulletin, 2007a, b).

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TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons of contained nickel unless otherwise specified)

| | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production | -- | -- | -- | -- | -- |
| Plant production | -- | -- | -- | -- | -- |
| Secondary recovery from purchased scrap: | | | | | |
| From ferrous scrap | 90,200 r | 91,400 r | 93,400 r | 92,700 r | 98,800 |
| From nonferrous scrap | 9,050 r | 9,500 r | 9,810 r | 8,820 r | 9,410 |
| Shipments of purchased scrap[2] | 130,000 r | 137,000 r | 133,000 r | 141,000 r | 147,000 |
| Exports: | | | | | |
| Primary | 6,520 | 6,330 | 8,000 | 7,630 | 8,050 |
| Secondary | 39,400 | 47,300 | 48,300 | 55,600 | 59,300 |
| Imports for consumption: | | | | | |
| Primary | 121,000 | 125,000 | 136,000 | 143,000 | 153,000 |
| Secondary | 9,110 | 11,500 | 18,800 | 15,500 | 20,300 |
| Consumption: | | | | | |
| Reported: | | | | | |
| Primary | 91,300 | 90,400 r | 102,000 r | 100,000 r | 124,000 |
| Secondary, purchased scrap[3] | 99,300 r | 101,000 r | 103,000 r | 101,000 r | 108,000 |
| Total | 191,000 r | 191,000 r | 205,000 r | 202,000 r | 233,000 |
| Apparent: | | | | | |
| Primary | 121,000 r | 117,000 | 128,000 | 135,000 r | 144,000 |
| Secondary, purchased scrap[4] | 69,100 r | 65,200 r | 74,500 r | 60,500 r | 69,000 |
| Total | 190,000 r | 182,000 r | 203,000 r | 196,000 r | 213,000 |
| Apparent primary plus reported secondary | 220,000 r | 218,000 r | 232,000 r | 236,000 r | 252,000 |
| Stocks, yearend: | | | | | |
| Producers and traders | 6,150 | 8,040 | 6,580 | 5,940 r | 6,450 |
| Consumer, primary | 4,540 r | 4,830 r | 5,770 r | 6,670 | 7,160 |
| Consumer, secondary | 7,000 r | 6,850 r | 6,110 r | 6,800 r | 6,910 |
| Total | 17,700 r | 19,700 r | 18,500 r | 19,400 r | 20,500 |
| Price, cash, London Metal Exchange: | | | | | |
| Average annual dollars per metric ton | 6,772 | 9,629 | 13,823 | 14,738 | 24,244 |
| Average annual dollars per pound | 3.072 | 4.368 | 6.270 | 6.685 | 10.997 |
| Price, 18/8 stainless steel scrap, gross weight:[5] | | | | | |
| Average annual dollars per metric ton | 692 | 927 | 1,450 | 1,445 | 2,057 |
| Average annual dollars per long ton | 703 | 942 | 1,473 | 1,468 | 2,090 |
| World, mine production | 1,350,000 | 1,370,000 | 1,420,000 r | 1,500,000 r | 1,580,000 e |

eEstimated. rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices; may not add to totals shown.
[2]Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.
[3]More clearly delineates the amount consumed than does apparent consumption.
[4]Internal evaluation indicates that apparent secondary consumption is considerably understated.
[5]Derived from the average of the Friday consumer buying price range for 18% chromium—8% nickel scrap in bundles, solids, and clips, Pittsburgh, PA, in American Metal Market.

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

(Metric tons of contained nickel)

| | 2005 | 2006 |
|---|---|---|
| Kind of scrap: | | |
| Aluminum-base[2] | 2,430 r | 2,950 |
| Copper-base | 2,970 r | 3,080 |
| Ferrous-base[3] | 92,700 r | 98,800 |
| Nickel-base | 3,420 r | 3,380 |
| Total | 101,000 r | 108,000 |
| Form of recovery: | | |
| Aluminum-base alloys | 2,430 r | 2,950 |
| Copper-base alloys | 3,620 r | 3,890 |
| Ferrous alloys | 93,100 r | 99,400 |
| Nickel-base alloys | 2,340 r | 2,010 |
| Miscellaneous and unspecified | -- r | 1 |
| Total | 101,000 r | 108,000 |

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

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

(Metric tons of contained nickel)

| Form | 2005 | 2006 |
|---|---|---|
| Primary: | | |
| Metal | 85,300 r | 106,000 |
| Ferronickel | 13,300 | 16,300 |
| Oxide and oxide sinter[2] | 168 r | 290 |
| Chemicals | 997 r | 880 |
| Other | 668 r | 1,060 |
| Total | 100,000 r | 124,000 |
| Secondary, scrap[3] | 101,000 r | 108,000 |
| Grand total | 202,000 r | 233,000 |

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4
U.S. CONSUMPTION OF NICKEL, BY USE[1]

(Metric tons of contained nickel)

| Use | 2006 | | | | | | | | Grand total in 2005 |
|---|---|---|---|---|---|---|---|---|---|
| | Metal | Ferronickel | Oxide and oxide sinter | Chemicals | Other forms | Total primary | Secondary (scrap) | Grand total | |
| Consumption reported: | | | | | | | | | |
| Cast irons[2] | 58 | W | W | -- | W | 58 | 5,290 | 5,350 | 180 r |
| Chemicals and chemical uses | 1,400 | -- | W | 535 | -- | 1,930 | W | 1,930 | 2,030 r |
| Electric, magnet, expansion alloys | 168 | -- | -- | -- | -- | 168 | W | 168 | 161 |
| Electroplating, sales to platers | 10,600 | -- | -- | 104 | -- | 10,700 | -- | 10,700 | 11,300 |
| Nickel-copper and copper-nickel alloys | 3,320 | -- | W | -- | 15 | 3,340 | 3,680 | 7,010 | 6,090 r |
| Other nickel and nickel alloys | 17,900 | W | W | -- | 41 | 17,900 | 1,680 | 19,600 | 18,800 |
| Steel: | | | | | | | | | |
| Stainless and heat resistant | 46,100 | 16,200 | 258 | W | 213 | 62,700 | 88,600 | 151,000 | 131,000 r |
| Alloys, excludes stainless | 3,430 | W | -- | W | W | 3,430 | 631 | 4,070 | 4,020 |
| Superalloys | 19,800 | -- | W | W | 607 | 20,400 | 100 | 20,500 | 18,000 r |
| Other[3] | 3,140 | 106 | 31 | 241 | 182 | 3,700 | 8,290 | 11,700 | 10,100 r |
| Total | 106,000 | 16,300 | 289 | 880 | 1,060 | 124,000 | 108,000 | 233,000 | 202,000 |
| Consumption, apparent | XX | XX | XX | XX | XX | 144,000 | 69,000 | 213,000 | 196,000 r |

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

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

(Metric tons of contained nickel)

| Form | 2005 | 2006 |
|---|---|---|
| Primary: | | |
| Metal | 4,810 r | 4,780 |
| Ferronickel | 944 | 1,030 |
| Oxide and oxide sinter | 68 | 71 |
| Chemicals | 778 | 1,220 |
| Other | 69 | 65 |
| Total | 6,670 r | 7,160 |
| Secondary, scrap | 6,800 r | 6,910 |
| Grand total | 13,500 r | 14,100 |

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

TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS[1, 2]

| Class | 2005 Quantity (metric tons of contained nickel) | 2005 Value (thousands) | 2006 Quantity (metric tons of contained nickel) | 2006 Value (thousands) |
|---|---|---|---|---|
| Primary: | | | | |
| Unwrought: | | | | |
| Cathodes, pellets, briquets, shot | 1,190 | $17,600 | 882 | $17,000 |
| Ferronickel | 72 | 520 | 67 | 986 |
| Powder and flakes | 1,910 | 33,900 | 1,030 | 30,900 |
| Metallurgical-grade oxide | 233 | 2,120 | 150 | 2,670 |
| Chemicals: | | | | |
| Catalysts | 2,150 | 134,000 | 2,570 | 184,000 |
| Salts[3] | 2,070 | 30,200 | 3,350 | 49,700 |
| Total | 7,630 | 219,000 | 8,050 | 286,000 |
| Secondary: | | | | |
| Stainless steel scrap | 43,800 | 670,000 | 38,000 | 716,000 |
| Waste and scrap | 11,700 | 60,000 | 21,300 | 149,000 |
| Total | 55,600 | 731,000 | 59,300 | 866,000 |
| Grand total | 63,200 | 949,000 | 67,300 | 1,150,000 |
| Wrought, not alloyed: | | | | |
| Bars, rods, profiles, wire | 215 | 4,030 | 293 | 7,090 |
| Sheets, strip, foil | 786 | 19,700 | 556 | 18,200 |
| Tubes and pipes | 335 | 3,030 | 381 | 3,000 |
| Total | 1,340 | 26,700 | 1,230 | 28,300 |
| Alloyed, gross weight: | | | | |
| Unwrought alloyed ingot | 10,400 | 99,900 | 7,550 | 122,000 |
| Bars, rods, profiles, wire | 16,400 | 374,000 | 18,800 | 569,000 |
| Sheets, strip, foil | 4,320 | 118,000 | 5,140 | 177,000 |
| Tubes and pipes | 3,000 | 81,200 | 4,410 | 94,700 |
| Other alloyed articles | 3,580 | 147,000 | 3,240 | 163,000 |
| Total | 37,700 | 819,000 | 39,200 | 1,120,000 |

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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.
[3]Excludes nickel carbonate (more information can be found in the Harmonized Tariff System Schedule B, export commodity code 2836.99.9050).

Source: U.S. Census Bureau.

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

(Metric tons of contained nickel)[2]

| | 2006 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | Cathodes, pellets, and briquets (unwrought) | Powder and flakes | Ferronickel | Metallurgical-grade oxide[3] | Waste and scrap | Stainless steel scrap | Chemicals | Total | Total in 2005 | Wrought nickel in 2006[4] |
| Australia | 1 | 9 | -- | -- | 423 | 21 | 1 | 455 | 537 | 34 |
| Belgium | -- | 21 | -- | 15 | 238 | 86 | 229 | 589 | 254 | 5 |
| Brazil | 18 | 29 | -- | 7 | -- | 10 | 11 | 75 | 52 | 7 |
| Canada | 40 | 120 | 10 | 1 | 9,280 | 2,410 | 2,190 | 14,100 | 12,700 | 87 |
| China | -- | 17 | 10 | 9 | 43 | 13,800 | 179 | 14,100 | 18,600 | 99 |
| Colombia | -- | 22 | -- | -- | (5) | 26 | 2 | 50 | 17 | 144 |
| Finland | -- | -- | -- | -- | -- | 3,740 | 169 | 3,910 | 5,210 | -- |
| France | -- | 26 | -- | (5) | 12 | 41 | 16 | 95 | 152 | 12 |
| Germany | 1 | 190 | -- | 65 | 703 | 65 | 140 | 1,160 | 768 | 48 |
| India | -- | 10 | -- | (5) | 20 | 2,030 | 3 | 2,060 | 2,700 | 17 |
| Italy | (5) | 10 | -- | -- | -- | 1,030 | 13 | 1,050 | 1,450 | 7 |
| Japan | 25 | 91 | -- | 10 | 8,740 | 1,050 | 336 | 10,200 | 1,190 | 94 |
| Korea, Republic of | 1 | 35 | -- | (5) | 307 | 1,850 | 228 | 2,420 | 4,020 | 105 |
| Mexico | 777 | 39 | (5) | 6 | 2 | 7 | 247 | 1,080 | 3,620 | 77 |
| Netherlands | -- | 2 | -- | -- | 120 | 542 | 157 | 821 | 1,040 | 10 |
| South Africa | -- | (5) | -- | 17 | 41 | (5) | 27 | 85 | 91 | 4 |
| Spain | -- | 1 | -- | -- | -- | 686 | 13 | 700 | 795 | -- |
| Sweden | -- | 22 | -- | -- | 324 | 4 | 5 | 355 | 408 | 1 |
| Taiwan | 5 | 63 | -- | (5) | 128 | 7,050 | 270 | 7,520 | 5,470 | 18 |
| Thailand | -- | 34 | -- | -- | -- | 729 | 69 | 832 | 86 | -- |
| United Kingdom | 1 | 88 | -- | 13 | 859 | 88 | 206 | 1,260 | 1,230 | 28 |
| Other | 13 | 198 | 47 | 7 | 62 | 2,670 | 1,410 | 4,410 | 2,840 r | 434 |
| Total | 882 | 1,030 | 67 | 150 | 21,300 | 38,000 | 5,920 | 67,300 | 63,200 | 1,230 |

rRevised. -- Zero.

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

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

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

[4]Excluded from "2006, total."

[5]Less than ½ unit.

Source: U.S. Census Bureau.

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

| Class | 2005 | | 2006 | |
|---|---|---|---|---|
| | Quantity (metric tons of contained nickel)[2] | Value (thousands) | Quantity (metric tons of contained nickel)[2] | Value (thousands) |
| Primary: | | | | |
| Unwrought: | | | | |
| Cathodes, pellets, briquets, shot | 110,000 | $1,620,000 | 125,000 | $2,560,000 |
| Ferronickel | 19,200 | 185,000 | 14,600 | 316,000 |
| Powder and flakes | 8,120 | 128,000 | 8,780 | 162,000 |
| Metallurgical-grade oxide | 1,540 | 24,500 | 1,210 | 25,500 |
| Chemicals: | | | | |
| Catalysts | 1,220 | 70,800 | 1,340 | 73,600 |
| Salts[3] | 2,410 | 39,100 | 2,340 | 46,700 |
| Total | 143,000 | 2,060,000 | 153,000 | 3,190,000 |
| Secondary: | | | | |
| Stainless steel scrap | 8,340 | 124,000 | 13,500 | 209,000 |
| Waste and scrap | 7,170 | 99,200 | 6,850 | 97,900 |
| Total | 15,500 | 223,000 | 20,300 | 307,000 |
| Grand total | 159,000 | 2,290,000 | 173,000 | 3,500,000 |
| Wrought, not alloyed: | | | | |
| Bars, rods, profiles, wire | 534 | 12,200 | 542 | 14,600 |
| Sheets, strip, foil | 419 | 11,100 | 468 | 12,200 |
| Tubes and pipes | 104 | 2,670 | 98 | 2,980 |
| Total | 1,060 | 26,000 | 1,110 | 29,900 |
| Alloyed, gross weight: | | | | |
| Unwrought alloyed ingot | 4,840 | 74,700 | 6,180 | 106,000 |
| Bars, rods, profiles, wire | 10,300 | 209,000 | 11,300 | 283,000 |
| Sheets, strip, foil | 3,490 | 83,700 | 3,870 | 112,000 |
| Tubes and pipes | 1,850 | 38,400 | 3,620 | 83,800 |
| Other alloyed articles | 2,800 | 75,500 | 2,240 | 56,500 |
| Total | 23,300 | 481,000 | 27,200 | 640,000 |

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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.
[3]Excludes nickel carbonate (more information can be found at Harmonized Tariff Schedule of the United States subheading 2836.99.5000).

Source: U.S. Census Bureau.

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

(Metric tons of contained nickel)[2]

| | 2006 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | Cathodes, pellets, and briquets (unwrought) | Powder and flakes | Ferronickel | Metallurgical-grade oxide[3] | Waste and scrap | Stainless steel scrap | Chemicals | Total | Total in 2005 | Wrought nickel in 2006[4] |
| Australia | 15,200 | 221 | -- | -- | 91 | -- | 1 | 15,500 | 12,100 | 8 |
| Austria | -- | 1 | -- | -- | 16 | -- | -- | 17 | 22 r | 66 |
| Belgium | -- | 117 | -- | -- | 70 | -- | 222 | 409 | 426 | 4 |
| Brazil | 1,080 | -- | -- | -- | 37 | 1 | -- | 1,110 | 1,450 | 1 |
| Canada | 55,700 | 3,900 | -- | 1,200 | 1,660 | 10,100 | 227 | 72,800 | 65,400 | 36 |
| Chile | -- | 1,220 | -- | -- | -- | -- | -- | 1,220 | 9 | -- |
| China | 1,120 | 17 | -- | -- | 95 | 4 | 117 | 1,350 | 611 | 18 |
| Colombia | -- | -- | 3,150 | -- | 20 | 92 | 2 | 3,260 | 3,730 | -- |
| Dominican Republic | -- | -- | 9,340 | -- | -- | 25 | -- | 9,360 | 13,800 | -- |
| Finland | 5,850 | 91 | 13 | -- | -- | 4 | 885 | 6,840 | 3,920 | -- |
| France | 1,290 | 1 | -- | -- | 848 | -- | 374 | 2,510 | 2,320 | 263 |
| Germany | 50 | 52 | -- | -- | 431 | 87 | 393 | 1,010 | 920 r | 391 |
| Japan | (5) | 94 | 187 | -- | 313 | 9 | 556 | 1,160 | 603 | 65 |
| Mexico | -- | (5) | -- | -- | 352 | 2,710 | 31 | 3,100 | 2,610 | 1 |
| Netherlands[6] | 106 | -- | -- | -- | -- | -- | 498 | 604 | 887 | (5) |
| New Caledonia | -- | -- | 1,910 | -- | -- | -- | -- | 1,910 | 1,500 | -- |
| Norway | 14,700 | -- | -- | -- | 30 | -- | -- | 14,800 | 19,400 | 12 |
| Russia | 28,000 | 1,200 | -- | -- | 20 | -- | -- | 29,200 | 22,200 | -- |
| South Africa | 55 | 774 | -- | -- | -- | -- | (5) | 828 | 669 | -- |
| United Kingdom | 141 | 903 | 4 | 8 | 1,860 | 48 | 93 | 3,060 | 2,770 | 186 |
| Venezuela | -- | -- | -- | -- | -- | 8 | 1 | 9 | 252 | -- |
| Zimbabwe | 1,190 | -- | -- | -- | -- | -- | -- | 1,190 | 1,550 | -- |
| Other | 45 | 182 | 1 | 1 | 1,010 | 415 | 281 | 1,930 | 1,320 r | 57 |
| Total | 125,000 | 8,780 | 14,600 | 1,210 | 6,860 | 13,500 | 3,680 | 173,000 | 159,000 | 1,110 |

rRevised. -- Zero.

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

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

[3]Primarily oxide, rondelles, and sinster.

[4]Excluded from "2006, total."

[5]Less than ½ unit.

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

Source: U.S. Census Bureau.

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

(Metric tons of nickel content)

| Country | 2002 | 2003 | 2004 | 2005 | 2006[e] |
|---|---|---|---|---|---|
| Australia, content of concentrate | 188,000 [r] | 191,000 [r] | 187,000 [r] | 189,000 | 185,000 |
| Botswana, content of ore milled | 28,600 | 38,230 [r] | 35,163 [r] | 39,305 [r] | 38,000 |
| Brazil, content of ore | 45,456 [r] | 44,928 [r] | 51,886 [r] | 74,198 [r] | 82,492 [p] |
| Burma, content of ore[e] | 10 | 10 | 10 | 10 | 10 |
| Canada, content of concentrate | 189,297 | 163,244 | 186,694 | 199,932 [r] | 233,461 [3] |
| China[e] | 53,700 | 61,000 | 75,600 | 72,700 [r] | 82,100 |
| Colombia, content of laterite ore | 58,196 | 70,844 | 75,032 | 89,031 | 94,105 [3] |
| Cuba, content of oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor[4] | 71,342 [r] | 74,018 [r] | 71,945 [r] | 73,753 [r] | 75,000 |
| Dominican Republic, content of laterite ore | 38,859 | 45,253 | 46,000 | 53,124 [r] | 46,526 [3] |
| Finland, content of concentrate[5] | 3,120 | 3,640 | 3,700 | 3,386 [r] | 2,985 [3] |
| Greece, content of laterite ore | 22,670 | 21,410 | 21,700 | 23,210 | 21,670 [3] |
| Indonesia, content of laterite ore | 143,000 [r] | 144,000 [r] | 136,000 [r] | 135,000 [r] | 140,000 |
| Kazakhstan, content of laterite ore | -- | -- | -- | 193 | 200 |
| Macedonia, content of ferronickel produced | 5,149 | 5,555 | 5,300 | 8,100 | 10,900 |
| Morocco, content of nickel sulfate | 109 | 126 | 130 | 199 [r, e] | 80 [3] |
| New Caledonia, content of ore | 99,841 | 112,013 | 119,199 [r] | 111,939 [r] | 102,986 [3] |
| Norway, content of concentrate[6] | 2,052 | 169 | 181 | 342 [r] | 362 [3] |
| Philippines: | | | | | |
| Content of ore | 24,148 [r] | 19,537 | 16,973 | 22,555 | 50,637 [3] |
| Content of concentrate[7] | -- | -- | -- | 4,081 | 8,242 [3] |
| Russia, content of ore[e] | 310,000 | 300,000 | 315,000 | 315,000 | 320,000 |
| South Africa, content of concentrate | 38,546 | 40,842 | 39,851 [r] | 42,392 [r] | 41,599 [p, 3] |
| Spain, content of concentrate | -- | -- | (8) | 5,398 | 6,400 |
| Turkey, content of laterite ore[9] | -- | 640 | 40 [e] | 400 [r, e] | 1,350 |
| Ukraine, content of laterite ore[e] | 2,000 | 2,000 | 2,000 | 6,000 [r] | 12,000 |
| Venezuela, content of laterite ore | 18,600 | 20,700 | 20,468 | 20,000 [e] | 20,000 |
| Zimbabwe, content of concentrate | 8,092 | 9,517 | 9,776 [r] | 8,556 [r] | 8,825 [3] |
| Grand total | 1,350,000 | 1,370,000 | 1,420,000 [r] | 1,500,000 [r] | 1,580,000 |
| Of which: | | | | | |
| Content of concentrate | 429,000 [r] | 408,000 [r] | 427,000 [r] | 453,000 [r] | 487,000 |
| Content of ore and ore milled | 508,000 [r] | 515,000 [r] | 538,000 [r] | 563,000 [r] | 594,000 |
| Content of laterite ore | 283,000 [r] | 305,000 [r] | 301,000 [r] | 327,000 [r] | 336,000 |
| Content of ferronickel produced | 5,150 | 5,560 | 5,300 | 8,100 | 10,900 |
| Content of nickel sulfate | 109 | 126 | 130 | 199 [r] | 80 |
| Content, unspecified and/or undifferentiated | 125,000 | 135,000 [r] | 148,000 | 146,000 [r] | 157,000 |

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

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

[2]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through August 3, 2007.

[3]Reported figure.

[4]The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 33% for leach ammoniacal precipitate.

[5]The gross weight of concentrates processed in Finland from domestic ores was, as follows, in metric tons: 2002—47,797, 2003—41,289; 2004—45,914; 2005—39,854; and 2006—40,000 (estimated).

[6]A/S Nikkel Og Olivin halted mining operations in October 2002. Outokumpu Oyj sold its 70% interest in the Norwegian mining company to Boliden AB on December 30, 2003.

[7]Nickel content of concentrate produced at Rio Tuba in 2005 and 2006 by Coral Bay Nickel Corp.

[8]The Aguablanca operation of Rio Narcea Gold Mines, Ltd. was commissioned in December 2004.

[9]European Nickel PLC began large scale heap-leaching trials at its Caldag laterite operation in October 2004. In 2006, the company began shipping laterite ore to the ferronickel smelter of GMM SA Larco in Greece.

TABLE 11
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of nickel content)

| Country and product[3] | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Australia: | | | | | |
| Metal | 120,800 | 115,800 | 112,400 r | 112,600 r | 105,100 |
| Unspecified[4] | 9,500 r | 11,800 r | 10,200 r | 9,700 r | 11,400 |
| Total | 130,300 r | 127,600 r | 122,600 r | 122,300 r | 116,500 |
| Austria, ferronickel and ferronickel molybdenum[e] | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |
| Brazil:[5] | | | | | |
| Ferronickel | 6,011 | 6,409 | 6,493 | 9,596 r | 10,670 P |
| Metal | 17,676 | 18,155 | 19,742 | 20,714 r | 23,029 P |
| Total | 23,687 | 24,564 | 26,235 | 30,310 r | 33,699 P |
| Canada, unspecified[6] | 144,476 | 124,418 | 151,518 | 139,683 | 153,743 |
| China, metal[e, 7] | 52,400 | 64,700 | 75,800 | 95,100 r | 112,000 |
| Colombia, ferronickel | 43,987 | 47,868 | 48,818 | 52,749 | 51,312 P |
| Cuba, oxide sinter and oxides[8] | 38,738 r | 42,282 r | 38,824 r | 39,121 r | 39,100 e |
| Dominican Republic, ferronickel | 23,303 | 27,227 | 29,477 | 28,668 | 29,700 e |
| Finland:[9] | | | | | |
| Metal | 49,151 | 45,417 | 40,088 | 34,709 r | 42,299 |
| Chemicals and unspecified | 6,197 r | 5,572 r | 9,492 r | 4,450 r | 5,170 |
| Total | 55,348 r | 50,989 r | 49,580 r | 39,159 r | 47,469 |
| France: | | | | | |
| Metal | 9,444 | 9,138 | 10,103 | 10,684 | 11,700 |
| Chemicals[e] | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| Total[10] | 11,444 | 11,138 | 12,103 | 12,684 | 13,700 |
| Greece, ferronickel | 19,229 | 18,000 | 18,115 | 19,235 | 17,740 P |
| Indonesia, ferronickel | 8,804 | 8,933 | 7,945 | 7,338 | 14,474 P |
| Japan: | | | | | |
| Ferronickel | 74,418 | 74,804 r | 73,655 r | 76,390 r | 66,058 |
| Metal | 32,303 | 34,991 | 32,769 | 29,794 r | 29,254 |
| Oxide sinter | 48,950 | 52,700 r | 60,300 r | 56,700 r | 57,400 e |
| Chemicals | 1,820 | 2,084 | 2,082 | 2,208 | 2,531 |
| Total | 157,491 | 164,579 r | 168,806 r | 165,092 r | 155,243 |
| Korea, Republic of, metal | (11) | (11) | (11) | (11) | (11) e |
| Macedonia, ferronickel | 5,149 | 5,555 | 5,300 | 8,100 | 10,900 |
| Morocco, chemicals | 109 | 126 | 130 | 130 e | 125 e |
| New Caledonia, ferronickel | 48,650 | 50,666 | 43,016 | 46,738 | 48,723 |
| Norway, metal | 68,530 | 77,183 | 71,410 | 84,886 | 81,974 P |
| Poland, chemicals[12] | 744 | 785 | 820 | 800 | 800 |
| Russia:[e] | | | | | |
| Ferronickel | 13,200 r | 13,900 r | 14,400 r | 13,400 r | 16,000 |
| Metal | 239,000 | 260,000 | 261,000 | 266,000 | 270,000 |
| Oxide sinter | 6,000 | 5,000 | 5,000 | 5,000 | 5,500 |
| Chemicals | 2,000 | 2,500 | 3,000 | 3,000 | 3,500 |
| Total | 260,000 r | 281,000 | 283,000 | 287,000 | 295,000 |
| South Africa: | | | | | |
| Metal | 31,646 | 25,500 e | 32,680 | 35,000 e | 34,200 e |
| Chemicals[13] | 6,900 | 15,342 | 7,170 e | 7,400 r, e | 7,600 e |
| Total | 38,546 | 40,842 | 39,850 | 42,400 r, e | 41,800 P |
| Taiwan, metal | (11) | (11) | (11) | (11) | (11) |
| Ukraine, ferronickel[e, 14] | 6,000 | -- | 12,000 | 14,000 | 18,000 |
| United Kingdom, metal | 33,790 | 26,788 | 38,606 | 37,127 | 36,800 |
| Venezuela, ferronickel | 15,500 | 17,200 | 17,400 | 16,900 e | 16,600 P |
| Zimbabwe, metal:[e] | | | | | |
| Refined from domestic materials[15] | 6,765 r, 16 | 9,500 r | 9,700 r | 7,500 r | 5,510 P |
| Toll refined from imported materials[17] | 10,812 16 | 7,300 r | 6,000 r | 5,700 r | 9,000 |
| Total | 17,577 r, 16 | 16,800 r | 15,700 r | 13,200 r | 14,510 P |

See footnotes at end of table.

TABLE 11—Continued
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of nickel content)

| Country and product[3] | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Grand total | 1,210,000 r | 1,230,000 r | 1,280,000 r | 1,300,000 r | 1,350,000 |
| Of which: | | | | | |
| Ferronickel | 266,000 r | 272,000 r | 278,000 r | 295,000 r | 302,000 |
| Metal | 672,000 r | 694,000 r | 710,000 r | 740,000 r | 761,000 |
| Oxide sinter | 93,700 r | 100,000 r | 104,000 r | 101,000 r | 102,000 |
| Chemicals | 19,800 r | 28,400 r | 24,700 r | 20,000 r | 21,700 |
| Unspecified | 154,000 r | 136,000 r | 162,000 r | 149,000 r | 165,000 |

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

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

[2]Table includes data available through August 3, 2007.

[3]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 12.

[4]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.

[5]Brazil produced nickel carbonate (an intermediate product), in metric tons: 2002—18,100; 2003—18,406; 2004—19,897; 2005—21,116 (revised); and 2006—21,000.

[6]Nickel contained in products of smelters and refineries in forms, which 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 11.

[7]In addition to metal, China produces a variety of nickel chemicals. Jinco Nonferrous Metals Co., Ltd. produces nickel chloride and nickel sulfate in Kunshan City, near Shanghai. The operation is a joint venture of Jike Mining Co. (35%) and Vale Inco Limited (65%). Jilin Jien Nickel Industry Co., Ltd. operates a mining, smelting, and refining complex at the base of Jilin Chang Bai Mountain. The Jien complex produces about 29,000 metric tons per year of nickel salts on a gross weight basis. Jien's nickel chemicals include acetate, chloride, fluoride, hydroxide, and sulfate. In 2006, China also reportedly produced ferronickel and nickeliferous pig iron. Ore to make the pig iron was imported from Indonesia, New Caledonia, and the Philippines.

[8]Cuba also produces nickel sulfide, but because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 2002—32,604 (revised); 2003—31,736; 2004—32,120 (revised); 2005—34,632 (revised); 2006—33,411 (preliminary). More information can be found in table 12.

[9]Part of the production is extracted from imported raw materials.

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

[11]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: 2002—30,337; 2003—31,340; 2004—27,200; 2005—26,300; 2006—21,000 (estimated). Taiwan: 2001—11,500; 2002–05—11,000; and 2006—11,000.

[12]Nickel content of nickel sulfate ($NiSO_4 \bullet 6H_2O$). 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.

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

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

[15]Data represent production from domestic nickel ore.

[16]Reported figure.

[17]Previously published as "Other, metal." Data represent production from matte imported from Botswana as well as nickel sulfate imported from South Africa.

TABLE 12

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

(Metric tons of nickel content)

| Country | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Matte: | | | | | |
| Australia[3] | 25,762 | 38,216 | 32,256 | 44,536 | 39,561 p |
| Botswana | 23,896 | 27,400 | 22,292 | 28,214 r | 29,400 p |
| Brazil[4] | 6,274 | 5,950 | 6,708 | 6,005 r | 5,416 p |
| Canada[5] | 53,135 r | 49,185 r | 61,115 r | 59,722 r | 60,000 e |
| China, exports[6] | -- | 4,530 | 20 | 26 | 758 |
| Indonesia[7] | 59,500 | 70,200 | 72,200 r | 76,400 | 71,700 |
| New Caledonia | 11,217 | 10,857 | 12,164 r | 12,838 | 13,655 |
| Russia[8] | 7,783 | 3,866 | 599 | 700 r | 1,300 |
| Total | 188,000 r | 210,000 r | 207,000 r | 228,000 r | 222,000 |
| Other, Cuba:[9] | | | | | |
| Sulfide precipitate | 30,858 | 29,620 r | 30,999 r | 32,354 r | 32,400 e |
| Ammoniacal liquor precipitate | 1,746 | 2,116 r | 2,121 r | 2,278 r | 2,300 e |
| Total | 32,604 | 31,736 r | 33,120 r | 34,632 r | 34,700 e |

eEstimated. pPreliminary. rRevised. -- Zero.

[1]Table includes data available through August 3, 2007. Data represent nickel content of matte and other intermediate materials produced for export.

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

[3]Total matte production on a contained nickel basis, in metric tons, was as follows: 2002—91,574; 2003—107,000; 2004—108,000 (estimated); 2005—96,000; and 2006—95,000. Figures exclude toll-refined material.

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

[5]Nickel content of reported exports. Matte from the Falconbridge smelter of Falconbridge Limited typically assays 55% nickel. Xstrata plc acquired the smelter at Falconbridge on November 1, 2006.

[6]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: 2002—59,200; 2003—69,300; 2004—74,000; 2005—115,000 (revised); and 2006—95,000.

[7]Represents the nickel output of the Soroako smelter. The Soroako matte, which also contains cobalt, is being shipped to Japan for further processing.

[8]Russian figures reported primarily for exports to China from 2002 to 2004. Sources: International Nickel Study Group; United Nations Statistics Division.

[9]Corrected for coproduct cobalt.

TABLE 13
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION BEFORE 2020, BY YEAR

| Projected year of first production | Country and state/province | Project and company[1] | Resource grade (% nickel) | Estimated resources (thousand metric tons)[2, 3] | Annual production capacity (metric tons of contained nickel) | Nickel product |
|---|---|---|---|---|---|---|
| 2007 | Philippines | Berong | 2.30 | 4,200 | 17,000 | Ore. |
| | (Palawan) | Toledo Mining Corp. PLC, Atlas Consolidated Mining and Development Corp., Investika Ltd. | 1.30 | 270,000 | | |
| 2008 | Australia | Ravensthorpe | 0.74 | 130,000 | 50,000 | Ni-Co hydroxide. |
| | (Western Australia) | BHP Billiton Group | 0.58 | 150,000 | | |
| 2009 | Brazil | Onca-Puma | 1.72 | 110,000 | 52,000 | Ferronickel. |
| | (Para) | Mineração Onça Puma Vale Inco Limited | 0.75 | 310,000 | | |
| 2009 | New Caledonia | Goro | 1.34 | 96,000 | 60,000 | Ni oxide. |
| | (Southern) | Goro Nickel S.A. | 2.01 | 24,000 | | |
| | | Vale Inco, Société de Participation Miniére du Sud Calédonien S.A.S., Sumitomo consortium | 1.70 | 83,000 | | |
| 2009 | Turkey | Caldag | 1.14 | 33,000 | 21,000 | Leachate precipitate. |
| | (Manisa) | European Nickel PLC and BHP Billiton Group | | | | |
| 2010 | Cameroon | Nkamouna and Mada | 0.69 | 55,000 | 3,000 | Ni oxide. |
| | (East Province) | Geovic Cameroon PLC. and Geovic Mining Corp. | 0.66 | 6,600 | | |
| | | | 0.47 | 26,000 | | |
| 2011 | Brazil | Barro Alto | 1.64 | 13,000 | 36,000 | Ferronickel. |
| | (Goias) | Anglo American plc | 1.81 | 27,000 | | |
| 2011 | Kazakhstan | Shevchenko | 0.85 | 21,000 | 15,700 | Ferronickel and/or leachate precipitate. |
| | (Kostanai Oblast) | Oriel Resources plc | 0.77 | 83,000 | | |
| | | | 0.84 | 32,000 | | |
| 2011 | Madagascar | Ambatovy (Ambatovy and Analamay deposits) | 1.12 | 44,000 | 60,000 | Ni-Co intermediate. |
| | | Sherritt International Corp., Sumitomo Corp., South Korean consortium | 0.99 | 81,000 | | |
| 2011 | New Caledonia | Koniambo | 2.40 | 63,000 | 60,000 | Ferronickel. |
| | (Northern) | Xstrata Nickel and Société Miniére du Sud Pacifique S.A. | 2.45 | 54,000 | | |
| | | | 2.20 | 160,000 | | |
| 2011 | Papua New Guinea | Ramu | 0.91 | 76,000 | 33,000 | Ni-Co intermediate. |
| | (Madang) | China Metallurgical Group Corp., Highlands Pacific Ltd., Mineral Resources Development Co., Mineral Resources Madang Ltd. | 1.01 | 67,000 | | |
| 2011 | Philippines | Pujada—Mati | 1.30 | 200,000 | 50,000 | Do. |
| | (Davao Oriental) | Hallmark Mining Corp., Austral—Asia Link Mining Corp. and BHP Billiton Group | | | | |
| 2012 | Brazil | Vermelho | 0.80 | 290,000 | 46,000 | Metal or oxide. |
| | (Para) | Vale Inco Limited | | | | |
| 2012 | China | Yuanjiang | 0.91 | 430,000 | NA | Ni-Co intermediate. |
| | (Yunnan) | Sino-Platinum Metals Co. | | | | |
| 2012 | Guatemala | Fenix saprolite (pyrometallurgical process) | 1.81 | 8,700 | 22,700 | Ferronickel. |
| | (Izabal) | Skye Resources Inc., Vale Inco Limited, BHP Billiton Group | 1.58 | 33,000 | | |
| | | | 1.76 | 44,000 | | |
| 2012 | Philippines | Adlay-Cagdianao-Tandawa | 1.61 | 5,800 | 5,000 | Ore. |
| | (Surigao del Norte and Surigao del Sur) | BHP Billiton Group and Case Mining and Development Corp. | 1.58 | 13,000 | | |
| 2013 | Australia | Marlborough (Slopeaway, Coorumburra, Whereat) | 0.99 | 12,000 | 65,000 | Metal. |
| | (Queensland) | | 0.91 | 43,000 | | |
| | | Gladstone Pacific Nickel Ltd. | 0.88 | 16,000 | | |
| 2013 | Australia | Jump-up Dam, Boyce Creek, Aubils | 1.01 | 22,000 | 5,000 | Leachate precipitate. |
| | (Western Australia) | Heron Resources Ltd. | 0.79 | 53,000 | | |
| 2013 | Guatemala | Sechol (El Inicio, El Segundo, Rio Negro, Poza Azul deposits) BHP Billiton Group[5] | 1.40 | 37,000 [4] | NA | Ni-Co intermediate. |
| | | | 1.50 | 100,000 | | |

See footnotes at end of table.

TABLE 13—Continued
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION BEFORE 2020, BY YEAR

| Projected year of first production | Country and state/province | Project and company[1] | Resource grade (% nickel) | Estimated resources (thousand metric tons)[2, 3] | Annual production capacity (metric tons of contained nickel) | Nickel product |
|---|---|---|---|---|---|---|
| 2013 | Indonesia (Halmahera Island) | Weda Bay (Santa Monica, Pintu, Boki Mokot deposits) | 1.45 | 150,000 | 60,000 | Ni-Co intermediate.[6] |
| | | | 1.53 | 120,000 | | |
| | | Weda Bay Minerals Inc. (Eramet Group) and PT Aneka Tambang | | | | |
| 2014 | Australia (New South Wales) | Syerston | 0.73 | 77,000 | 18,000 | Ni-Co sulfide concentrate. |
| | | Ivanhoe Nickel and Platinum Ltd. | | | | |
| 2014 | Australia (Western Australia) | Kalgoorlie and North Kalgoorlie—Ghost Rocks, Goongarrie, Kalpini | 1.20 | 100,000 | 50,000 | Ni-Co hydroxide. |
| | | | 0.83 | 230,000 | | |
| | | Heron Resources Ltd. and Vale Inco Limited | | | | |
| 2014 | Cuba (Holguin) | Las Camariocas | 1.32 | 110,000 | 22,500 | Metal, oxide, or ferronickel. |
| | | Government of Cuba and others[7] | | | | |
| 2014 | Indonesia (Sulawesi) | Sorowako and Bahodopi mines | 1.87 | 48,000 | 22,000 | Leachate precipitate. |
| | | PT International Nickel Indonesia TBK | | | | |
| 2014 | Philippines (Mindoro Oriental) | Sablayan (Kisluyan, Buraboy, Shabo areas) | 0.94 | 73,000 | 60,000 | Ni-Co sulfide. |
| | | Aglubang Mining Corp. | 0.95 | 47,000 | | |
| | | Crew Minerals ASA | 0.88 | 88,000 | | |
| 2014 | Philippines (Zambales) | Acoje and Zambales | 1.13 | 49,000 | 17,000 | Leachate precipitate. |
| | | DMCI Holdings, Inc., Rusina Mining NL, European Nickel PLC | 1.18 | 24,000 | | |
| 2015 | Australia (New South Wales) | Young | 0.99 | 58,000 | 27,000 | Leachate precipitate or ferronickel. |
| | | Jervois Resources Ltd. | 0.72 | 110,000 | | |
| | | | 0.38 | 110,000 | | |
| 2015 | Australia (Western Australia) | Mount Margaret | 0.78 | 170,000 | 45,000 | Ni-Co hydroxide. |
| | | Minara Resources Ltd. | | | | |
| 2015 | Cuba (Holguin) | Pinares de Mayari West | 1.10 | 400,000 | 40,000 | Metal, oxide, or ferronickel. |
| | | Government of Cuba | | | | |
| 2015 | Guatemala (Izabal) | Fenix limonite (hydrometallurgical process) | 1.18 | 52,000 | 22,200 | Ni-Co hydroxide. |
| | | Skye Resources Inc., Vale Inco Limited, BHP Billliton Group | 1.16 | 13,000 | | |
| 2015 | New Caledonia (Southern) | Prony | 1.50 | NA[4] | NA[4] | Ni oxide. |
| | | Vale Inco, Bureau de Recherches, Géologiques et Miniéres, Sumitomo consortium | | | | |
| 2016 | Brazil (Para) | Araguaia (Serra do Tapa, Vale dos Sonhos, Pau Preto) | 1.62 | 44,000 | 36,000 | Ferronickel. |
| | | | 1.64 | 18,000 | | |
| | | Xstrata Nickel | 1.60 | 7,000 | | |
| 2016 | Cuba (Camaguey) | San Felipe | 1.30 | 250,000 | 45,000 | Metal or oxide. |
| | | Government of Cuba and others | | | | |
| 2016 | Papua New Guinea (Oro) | WoWo Gap | 1.09 | 31,000 | 45,000 | Metal. |
| | | Resource Mining Corp. Ltd. | 1.44 | 18,000 | | |
| 2017 | New Caledonia (Northern) | Nakety-Bogota | 1.47 | 88,000 | 52,000 | Ni-Co intermediate. |
| | | Argosy Minerals, Inc. and Société des Mines de la Tontouta | 1.50 | 140,000 | | |
| 2018 | Philippines (Palawan) | Celestial | 1.29 | 77,000 | 40,000 | Do. |
| | | Celestial Nickel Mining Exploration | 1.30 | 120,000 | | |
| | | Toledo Mining Corp. | | | | |
| 2019 | Dominican Republic (Las Jarditas) | Cerro de Maimon (Cumpie Hill, Loma Mala, Corozal Ridge) | 1.70 | NA[4] | NA | NA |
| | | GlobeStar Mining Corp. | | | | |
| 2019 | Indonesia (Sulawesi) | La Sampala | 1.50 | 200,000 | 46,000 | NA |
| | | Rio Tinto plc | 1.30 | 190,000 | | |
| 2020 | Albania (Korce District) | Devolli (Verniku and Kapshtica West) | 1.19 | 22,000 | NA | Leachate precipitate. |
| | | European Nickel PLC | 1.21 | 14,000 | | |

See footnotes at end of table.

TABLE 13—Continued
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION BEFORE 2020, BY YEAR

| Projected year of first production | Country and state/province | Project and company[1] | Resource grade (% nickel) | Estimated resources (thousand metric tons)[2, 3] | Annual production capacity (metric tons of contained nickel) | Nickel product |
|---|---|---|---|---|---|---|
| 2020 | Australia (Western Australia) | Wingellina<br>Metals X Ltd. and Jinchuan Group Ltd. | 0.95 | 210,000 | 40,000 | Ni-Co hydroxide. |
| 2020 | Côte d'Ivoire | Biankouma, Touba, Sipilou<br>Xstrata Nickel and Société d'État pour le Developpement Minier | 1.57<br>1.40 | 120,000<br>140,000 | 45,000 | Ni-Co intermediate or ferronickel. |
| 2020 | Indonesia (Maluku) | Gag Island<br>BHP Billiton Group, PT Aneka Tambang, Xstrata Nickel | 1.35 | 240,000 | 30,000 | Intermediate, metal, or ferronickel. |

NA Not available.
[1]Company names reflect organizational structure as of August 3, 2007. BHP Billiton Group is a dual listed company comprising of BHP Billiton Limited and BHP Billiton Plc. Vale Inco Limited is a wholly owned subsidiary of Companhia Vale do Rio Doce.
[2]Gross weight, dry.
[3]"Estimated resources" are rounded to no more than two significant digits. When two or more data sets are listed, the first resource data represent measured resources; the second, indicated resources; and the third, inferred resources.
[4]New resource estimate in progress.
[5]Purchased from Jaguar Nickel S.A. in 2005.
[6]Proprietary process currently under development by Centre de Recherche de Trappes (France).
[7]China Minmetals Corporation and the Government of Venezuela have both expressed an interest in investing in this long-stalled project.

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

TABLE 14
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION BEFORE 2020, BY YEAR

| Projected year of first production | Country and state/province | Project and company[1] | Resource grade (% nickel) | Estimated resources (thousand metric tons)[2, 3] | Annual production capacity (metric tons of contained nickel) | Nickel product |
|---|---|---|---|---|---|---|
| 2006 | Australia | Forrestania-Flying Fox, New Morning, | 5.42 | 1,200 | 7,000 | Concentrates. |
| | (Western Australia) | Diggers South | 6.51 | 1,400 | | |
| | | Western Areas NL | 1.94 | 9,400 | | |
| 2006 | do. | Lanfranchi—Deacon, Helmut South, Winner | 2.59 | 2,400 | 6,300 | Ore. |
| | | Sally Malay Mining Ltd., Donegal Resources Ltd. | | | | |
| 2006 | do. | Waterloo and Amorac | 3.50 | 299 | 10,000 | Concentrates. |
| | | LionOre Australia Ltd.[4] | | | | |
| 2007 | Australia | Avebury | 1.16 | 3,300 | 8,500 | Do. |
| | (Tasmania) | Allegiance Mining NL | 0.97 | 13,000 | | |
| 2008 | Australia | Prospero, Tapinos, Alec Mairs, Anomaly 1, | 4.73 | 2,700 [5] | 10,000 | Do. |
| | (Western Australia) | Sinclair | 0.62 | 53,000 | | |
| | | Jubilee Mines NL[6] | | | | |
| 2008 | Canada | Podolsky, '2000' and Whistle Pit | 0.75 | 6,700 | 3,300 | Ore. |
| | (Ontario) | FNX Mining Company, Inc. | 0.30 | 3,200 | | |
| | | | 0.15 | 4,900 | | |
| 2008 | do. | Shakespeare | 0.33 | 12,000 | 4,500 | Concentrates. |
| | | URSA Major Minerals Inc. | 0.37 | 1,800 | | |
| 2009 | Brazil | Santa Rita | 0.62 | 9,600 | 18,500 | Concentrates or matte. |
| | (Bahia) | Mirabela Nickel Ltd. | 0.56 | 79,000 | | |
| | | | 0.51 | 15,000 | | |
| 2009 | Canada | Bucko Lake | 1.84 | 2,400 | 5,700 | Concentrates. |
| | (Manitoba) | Crowflight Minerals Inc. and Xstrata plc | 2.01 | 100 | | |
| | | | 2.23 | 1,200 | | |
| 2009 | Canada | Nickel Rim South | 1.70 | 14,000 | 10,000 | Do. |
| | (Ontario) | Xstrata Nickel | | | | |
| 2009 | Finland | Talvivaara (Kuusilampi and Kolmisoppi) | 0.27 | 340,000 | 33,000 | Bioleachate. |
| | (Oulu) | Talvivaara Mining Company Ltd. | 0.27 | 78,000 | | |
| 2009 | Finland | Kylylahti copper-cobalt | 0.22 | 7,900 | 1,000 | Ni-Co hydroxide. |
| | (Pohiois) | Vulcan Resources Ltd. | | | | |
| 2009 | United States | NorthMet | 0.08 | 250,000 | 7,100 | Byproduct concentrate |
| | (Minnesota) | PolyMet Mining Corp. | 0.08 | 330,000 | | of Ni-Co hydroxide. |
| 2009 | Vietnam | Ban Phuc | 2.40 | 1,010 | 4,000 | Concentrates. |
| | (Son La) | Asian Mineral Resources Ltd. | 2.77 | 220 | | |
| 2009 | Zambia | Munali (Enterprise deposit) | 1.23 | 6,700 | 8,500 | Do. |
| | | Albidon Limited | 1.40 | 1,300 | | |
| 2009 | Zimbabwe | Hunters Road | 0.56 | 29,000 | 2,000 | Do. |
| | | Bindura Nickel Corp. | 0.50 | 7,000 | | |
| 2010 | Australia | Sherlock Bay | 0.49 | 33,000 | 8,500 | Precipitated leachate. |
| | (Western Australia) | Australasian Resources Ltd. | | | | |
| 2010 | Canada | Fraser Morgan | 1.86 | 3,400 | 7,500 | Concentrates. |
| | (Ontario) | Xstrata Nickel | 1.69 | 1,600 | | |
| | | | 1.80 | 2,400 | | |
| 2010 | United States | Eagle | 3.80 | 3,600 | 27,000 | Ore. |
| | (Michigan) | Kennecott Minerals Company | 2.20 | 500 | | |
| 2011 | Canada | Totten | 0.74 | 6,000 | 8,200 | Concentrates. |
| | (Ontario) | Vale Inco Limited | 0.75 | 550 | | |
| 2011 | South Africa | Sheba's Ridge | 0.18 | 410,000 | 23,700 | Do. |
| | (Mpumalanga) | Ridge Mining plc and Anglo Platinum Ltd. | 0.18 | 310,000 | | |
| | | | 0.17 | 53,000 | | |
| 2012 | Australia | Honeymoon Well and Avalon (Bulong) | 0.65 | 120,000 | 40,000 | Concentrates, initially. |
| | (Western Australia) | LionOre Australia Ltd.[4] and OM Group, Inc.[7] | 0.65 | 120,000 | | |

See footnotes at end of table.

TABLE 14—Continued
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION BEFORE 2020, BY YEAR

| Projected year of first production | Country and state/province | Project and company[1] | Resource grade (% nickel) | Estimated resources (thousand metric tons)[2, 3] | Annual production capacity (metric tons of contained nickel) | Nickel product |
|---|---|---|---|---|---|---|
| 2012 | Australia (Western Australia) | Yakabindie<br>BHP Billiton Group | 0.58<br>0.60 | 250,000<br>190,000 | 40,000 | Ore. |
| 2012 | Finland | Kuhmo (Peura-aho, Hietaharju, Vaara)<br>Vulcan Resources Limited and Polar Mining OV | 0.38 | 7,700 | 3,000 | Ni-Co hydroxide. |
| 2012 | Russia (Amur) | Kun-Manie (Vodorazdelny, Ikensoe, Maly Krumkon, Falcon)<br>Amur Minerals Corp. | 0.61<br>0.48<br>0.54 | 3,700<br>48,000<br>17,000 | 16,000 | Concentrates. |
| 2012 | Tanzania (Kagera region) | Kabanga<br>Barrick Gold Corp. and Xstrata Nickel | 2.35<br>2.80 | 9,300<br>39,000 | 30,000 | Do. |
| 2012 | United States (Minnesota) | Mesaba<br>Teck Cominco American, Inc. | 0.12 | 300,000 | 20,000 | Byproduct concentrate of Ni-Co sulfide or hydroxide. |
| 2013 | United States (Minnesota) | Birch Lake, Maturi, Spruce Road<br>Franconia Minerals Corp. | 0.19<br>0.26<br>0.14 | 100,000<br>83,000<br>28,000 | 8,600 | Byproduct concentrate of Ni-Co hydroxide. |
| 2014 | Canada (Manitoba) | Maskwa<br>Mustang Minerals Corp. | 0.77<br>0.59<br>0.40 | 590<br>9,500<br>830 | 3,800 | Ore. |
| 2015 | Canada (Quebec) | Nunavik/South Raglan (Allammaq, Mesamax, Mequillon, Expo, Ivakkak, TK deposits)<br>Canadian Royalties Inc. | 0.91<br>0.87 | 16,000<br>720 | 6,800 | Concentrates. |
| 2015 | United States (Minnesota) | Nokomis/Maturi Extension<br>Duluth Metals Ltd[8] | 0.20<br>0.18 | 350,000<br>110,000 | 10,800 | Byproduct concentrate of Ni-Co sulfide or hydroxide. |
| 2017 | Canada (Ontario) | Kelly Lake<br>Vale Inco | 1.77 | 11,000 | NA | Concentrates. |
| 2018 | do. | Victoria<br>FNX Mining Company Inc. | 0.48<br>0.46 | 10,000<br>17,000 | NA | Ore. |
| 2019 | do. | Kirkwood<br>FNX Mining Company Inc. | 0.52<br>0.73 | 9,400<br>7,300 | NA | Do. |

NA Not available.

[1]Company names reflect organizational structure as of March 2008. BHP Billiton Group is a dual listed company comprising of BHP Billiton Limited and BHP Billiton Plc.

[2]Gross weight, dry.

[3]"Estimated resources" are rounded to no more than two significant digits. When two or more data sets are listed, the first resource data represent measured resources; the second, indicated resources; and the third, inferred resources.

[4]Acquired by MMC Norilsk Nickel Group in August 2007.

[5]Resources estimate includes the Sinclair deposit, 100 kilometers south of the Cosmos operations.

[6]Acquired by Xstrata Nickel in February 2008.

[7]Acquired by MMC Norilsk Nickel in March 2007.

[8]Formerly Wallbridge America Corp., a U.S. subsidiary of Wallbridge Mining Company Ltd., that was spun off in 2006.

Sources: Canadian Minerals Yearbook 2005; company annual reports, presentations, and press releases; and CRU International, Ltd.