2006 Minerals Yearbook

SULFUR

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

June 2008

SULFUR

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For the second consecutive year, domestic recovered sulfur output was lower in 2006 than it was the previous year. By yearend, the U.S. refining industry mostly had recovered from two devastating hurricanes that had struck the Gulf Coast region of the United States in August and September 2005 and caused major refinery shutdowns in Louisiana and Texas; the impact of the storms was felt early in the year. Sulfur recovered from natural gas operations decreased dramatically owing to the successful implementation of an acid-gas reinjection project in Wyoming. Total elemental sulfur production was 4.6% lower than it was in 2005. Production of sulfur from petroleum refineries was virtually the same in 2006 as it was in 2005, but sulfur from natural gas processing was 23% lower.

Canadian sulfur production was virtually the same as that of the United States; the totals for both countries were less than 1% different. Elemental sulfur and byproduct sulfuric acid produced as a result of efforts to meet environmental requirements that limit atmospheric emissions of sulfur dioxide were the dominant sources of sulfur around the globe. Worldwide, compliance with environmental regulations contributed to sulfur recovery, although the increases were relatively modest. Estimated worldwide production of native sulfur was slightly higher. In the few countries where pyrites remain an important raw material for sulfuric acid production, sulfur production from pyrites decreased slightly.

Production continued to outpace sulfur demand, although the difference was less than it had been for several years. Stocks increased at a few operations, especially those in very remote locations from which it was difficult and costly to ship the product to market. There was some remelting of more market-accessible stockpiles to meet strong global demand, and the net increase in sulfur stocks was relatively low.

Through its major derivative, sulfuric acid, sulfur ranks as one of the most important elements used as an industrial raw material and is of prime importance to every sector of the world's fertilizer and manufacturing industries. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indexes of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other inorganic chemical; 35.9 million metric tons (Mt), which is equivalent to about 11.7 Mt of elemental sulfur, was produced in 2006, which is 3.4% more than was produced 2005 (U.S. Census Bureau, 2007).

In 2006, all salient U.S. sulfur statistics were lower than the corresponding data in 2005 except imports, stocks, and total and unit value of elemental sulfur. Domestic production and shipments of sulfur in all forms were 4.6% and 5.4% lower, respectively, than those of 2005. Byproduct sulfuric acid production was 5.2% lower. Consumption decreased by 3.1%, and exports decreased by 10%. Total imports were slightly higher in 2006, although imports of elemental sulfur increased by 4.6%, and imports of sulfuric acid decreased by 9.6% compared with those of 2005. Unit prices averaged about 6.4% higher for the year, resulting in a slightly higher value for elemental sulfur shipments, but the total value of byproduct sulfuric acid decreased by 19%. Producer stocks increased by 38%, although the 221,000 metric tons (t) reported by producers represented less than 3% of elemental sulfur production (table 1).

Estimated world sulfur production was virtually the same in 2006 as it was in 2005. Recovered elemental sulfur is produced primarily during the processing of natural gas and crude petroleum. For the past 5 years, an average of about 84% of the world's sulfur production came from recovered sources. Some sources of sulfur are unspecified, which means that the material could be, and likely is, elemental or byproduct sulfuric acid, raising the percentage of byproduct sulfur production to about 90% annually. The quantity of sulfur produced from recovered sources was dependent on the world demand for fuels, nonferrous metals, and petroleum products, rather than for sulfur.

World sulfur consumption was slightly higher than it was in 2005; about 50% was used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur increased slightly from the levels recorded in 2005. Worldwide inventories of elemental sulfur were relatively unchanged.

Legislation and Government Programs

The U.S. Environmental Protection Agency (EPA) moved the retail compliance date for availability of ultralow sulfur diesel (ULSD) from September 1, 2006, to October 15, 2006, to give retailers more time to comply with the 15-parts-per-million (ppm) requirement. During this time, 22-ppm diesel was allowed to be marketed as ULSD to ensure a smooth transition to the lower standard (Sulphur, 2005c). Regulations mandated that 80% of all diesel fuel sold in the United States be ULSD by 2006. Surveys of retail fueling stations conducted by the EPA at the end of 2006 indicated that ULSD composed 85% of available on-road diesel, significantly ahead of schedule. By 2010, all highway diesel must be ULSD (Sulphur, 2007c).

The U.S. Department of Energy's (DOE's) Clean Coal Initiative holds the potential for significant quantities of sulfur being recovered from coal gasification. Projects that use integrated gasification combined cycle (IGCC) technology to convert coal to natural gas for electric powerplants reduce emissions from power generation. IGCC is considered the cleanest and most efficient coal-burning technology. The process can recover elemental sulfur, sulfuric acid, or ammonium sulfate, all of which have a commercial market. In February, DOE approved funding for a project in central Florida that was expected to be in operation by 2010 (Sulphur, 2006f).

Production

Recovered Elemental Sulfur.—U.S. production statistics are collected on a monthly basis and published in the U.S. Geological Survey (USGS) Mineral Industry Surveys. For 2006, all the 107 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2006, production and shipments were 4.6% and 5.4% lower than those of 2005, respectively. The value of shipments was slightly higher than that in 2005 owing to a 6.4% increase in the average domestic unit value of elemental sulfur.

Production from petroleum refineries was slow to recover after Hurricanes Katrina and Rita. These storms, which made landfall in the U.S. Gulf Coast area on August 29 and September 24, 2005, respectively, led to decreased sulfur production as a result of precautionary measures taken at oil refineries to prepare for the hurricanes and downtime to repair damage caused by the storms. A total of 28 petroleum refineries were affected to varying degrees by the hurricanes, with a few being out of commission for several months. ConocoPhillips Co. restarted its Alliance refinery near New Orleans, LA, at the end of January 2006 (ConocoPhillips Co., 2006, p. 6). Murphy Oil Corp.'s Meraux, LA, refinery was seriously damaged by Hurricane Katrina, and the necessary repairs kept the refinery inoperable well into 2006, with startup beginning in the first week of May (Murphy Oil Corp., 2006, p. 21).

Another factor that negatively affected sulfur recovery from petroleum refineries was that BP p.l.c. produced no sulfur at its Texas City, TX, refinery during 2006. Sulfur production from this refinery would typically be about 300,000 metric tons per year (t/yr), but the refinery was inoperable for much of 2006 while repairs and upgrades were being made after an explosion in 2005. As the refinery was ramped up to full production, it processed sweet crudes and did not recover sulfur. The sulfur recovery unit improvements were among the last to be completed. The refinery was not expected to reach full capacity until late in 2007 (North American Sulphur Review, 2006f). Other refineries experienced unexpected maintenance problems that reduced sulfur production for varying amounts of time throughout the year. One example was an explosion that curtailed operations at Valero Energy Corp.'s refinery in Norco, LA, in May. It took about 1 month for production to return to normal levels, including sulfur production at the site (Green Markets, 2006a).

Recovery from natural gas operations dropped significantly as the result of the successful implementation of a reinjection project at Exxon Mobil Corp.'s LaBarge operation in Wyoming, as well as decreased production from other Wyoming gas plants. The ExxonMobil reinjection project took about 400,000 t/yr out of production (North American Sulphur Review, 2006f).

Recovered elemental sulfur, which is a nondiscretionary byproduct from petroleum-refining, natural-gas-processing, and coking plants, was produced primarily to comply with environmental regulations that were applicable directly to emissions from the processing facility or indirectly by restricting the sulfur content of the fuels sold or used by the facility. Recovered sulfur was produced by 40 companies at 107 plants in 26 States and 1 plant in the U.S. Virgin Islands. The size of the sulfur recovery operations varied greatly from plants that produced more than 500,000 t/yr to others that produced less than 500 t/yr. Of all the sulfur operations canvassed, 31 produced more than 100,000 t of elemental sulfur in 2006; 18 produced between 50,000 and 100,000 t; 32 between 10,000 and 50,000 t; and 26 plants, less than 10,000 t. By source, 83% of recovered elemental sulfur production came from petroleum refineries or satellite plants that treated refinery gases and coking plants; the remainder was produced at natural-gas-treatment plants (table 3).

The leading producers of recovered sulfur, all with more than 500,000 t of sulfur production were, in descending order of production, Valero, ExxonMobil, ConocoPhillips, Chevron Corp., Shell Oil Co. (including its joint ventures with Petróleos Mexicanos, S.A. de C.V. and Saudi Refining Inc. and subsidiary operations), and BP. The 45 plants owned by these companies accounted for 68% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

Refining companies made acquisitions in 2006 that affected their sulfur production. ConocoPhillips acquired Burlington Resources Inc. during the year. The Lost Cabin gas processing plant in Wyoming, which was the most important domestic component of the acquisition, was the single largest sulfur source in the country, with the capacity to produce more than 500,000 t/yr. Burlington was attractive to ConocoPhillips because of its large natural gas reserves in North America and exploration and development programs in Africa, Canada, China, South America, and the United Kingdom (North American Sulphur Review, 2006a). Lyondell Chemical Co. bought the 41.25% interest of the joint-venture refinery in Houston, TX, that had been owned by its partner in the operation, Citgo Petroleum Corp. (Balboa, 2006).

Refining companies announced major expansions to refineries in the United States that would result in additional sulfur capacity. Chevron Corp. announced plans to double the size of its Pascagoula, MS, refinery. Sulfur production there could increase by as much as 600,000 t/yr, and perhaps more if facilities are added to handle more sour crude. Marathon Petroleum Co. LLC planned to increase throughput at its Garyville, LA, refinery by 70%, by acquiring the necessary apparatus to handle heavy, sour crudes. This could increase sulfur recovery by 170,000 t/yr (North American Sulphur Review, 2006c).

Other refiners across the country were investing in upgrades at refineries to enable them to process lower quality crude petroleum such as the material obtained from Canadian oil sands operations. These crudes are more difficult to process and usually contain a significantly higher percentage of sulfur, but they can be attractive to refiners because they can also be much lower in price. During 2006, at least 57 such projects representing more than $5.3 billion in investments were underway or planned and were expected to be completed by 2012 (North American Sulphur Review, 2006e). Examples of this type of project included BP's plans to upgrade its Whiting, IN, refinery to enable the refinery to process higher sulfur crudes. The proposed changes, which were expected to be completed in 2011, would increase sulfur recovery capacity by about 650,000 t/yr. ConocoPhillips entered a partnership agreement with EnCana Corp. that included expansions of heavy oil processing capacity at ConocoPhillips' Wood River, IL, and Borger, TX, refineries. Additional sulfur supplies resulting from this agreement were expected to be more than 500,000 t/yr (North American Sulphur Review, 2006g). Suncor Energy, Inc. completed upgrades at its Commerce City, CO, refinery to enable the plant to process high-sulfur crudes from its oil sands operations in Fort McMurray, Alberta, Canada (Sulphur, 2006g).

Of the 20 largest oil refineries in the world, 5 are U.S. operations: BP's Texas City, TX, refinery; Citgo's Lake Charles, LA, refinery; ExxonMobil's refineries in Baytown, TX, and Baton Rouge, LA; and Hovensa L.L.C.'s St. Croix, U.S. Virgin Islands, refinery. The capacity to process large quantities of crude oil does not necessarily mean that refineries recover large quantities of sulfur, but all of these refineries were major producers of refinery sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the types of crude oil that are refined at the specific refineries. Major refineries that process low-sulfur crudes may have relatively low sulfur production. According to a survey conducted by Oil & Gas Journal, U.S. refining capacity represents 20% of the world total, but sulfur recovery capacity at U.S. refineries represent 41% of the world total (Nakamura, 2006).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 7.4% of the total domestic production of sulfur in all forms and totaled the equivalent of 674,000 t of elemental sulfur. Although the portion of total sulfur product was about the same as that of 2005, the quantity produced was 5.2% lower (table 4). Three acid plants operated in conjunction with copper smelters, and four were byproduct operations of lead, molybdenum, and zinc smelting and roasting operations. The three largest sulfuric acid plants in terms of size and capacity were associated with copper mines and accounted for 81% of the output. The copper producers—ASARCO LLC, Kennecott Utah Copper Corp., and Phelps Dodge Corp.—each operated a sulfuric acid plant at its primary copper smelter. ASARCO's and Kennecott Utah Copper's smelters suspended production for extended periods during the second half of the year (North American Sulphur Review, 2006f). In November, Freeport McMoRan Copper & Gold Inc. agreed to buy Phelps Dodge Corp. With completion of the acquisition, which was expected during 2007, Freeport would become the world's leading publicly traded copper producer. Corporación Nacional del Cobre de Chile would be the only company in the world with higher annual copper production (North American Sulphur Review, 2006e).

Consumption

Apparent domestic consumption of sulfur in all forms was 3.1% lower than that of 2005 (table 5). Of the sulfur consumed, 69% was obtained from domestic sources—elemental sulfur (64%) and byproduct acid (5.0%)—compared with 70% in 2005 and 72% in 2004 and 2003. The remaining 31% was supplied by imports of recovered elemental sulfur (25%) and sulfuric acid (6.6%). The USGS collected end-use data on sulfur and sulfuric acid according to the standard industrial classification of industrial activities (table 6).

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The leading sulfur end use, sulfuric acid, represented 62% of reported consumption with an identified end use. It is reasonable to assume that nearly all the sulfur consumption reportedly used in petroleum refining was first converted to sulfuric acid, bringing sulfur used in sulfuric acid to 85% of the total. Some identified sulfur end uses were included in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use also were tabulated as "Unidentified." A significant portion of the sulfur in the "Unidentified" category may have been shipped to sulfuric acid producers or exported, although data to support such assumptions were not available.

Because of its desirable properties, sulfuric acid retained its position as the most universally used mineral acid and the most produced and consumed inorganic chemical, by volume. Data based on USGS surveys of sulfur and sulfuric acid producers showed that reported U.S. consumption of sulfur in sulfuric acid (100% basis) decreased by 9.8%, and total reported sulfur production decreased by 7.5%. These decreases in consumption can be attributed, in large part to the decrease in sulfuric acid consumed in phosphatic fertilizer production. Reported consumption figures do not correlate with calculated apparent consumption owing to reporting errors and possible double counting in some data categories. These data are considered independently from apparent consumption as an indication of market shares rather than actual consumption totals.

Agriculture was the leading sulfur-consuming industry; consumption in this end use decreased by 9.0% to 8.24 Mt compared with 9.05 Mt in 2005. Reported consumption of sulfur in the production of phosphatic fertilizers was 12% lower than that of 2005, but reported consumption of sulfur used in other agricultural chemicals, including sulfur fertilizers, increased by 11%. Based on export data reported by the U.S. Census Bureau (2007), the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased by 8.1% to 4.7 Mt.

The second ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported an 8.8% decrease in the consumption of sulfur in that end use. Demand for sulfuric acid in copper ore leaching, which was the third ranked end use, decreased by 17% because production of electrowon copper decreased.

The U.S. Census Bureau (2007) also reported that 2.6 Mt of sulfuric acid was produced as a result of recycling spent and contaminated acid from petroleum alkylation and other processes. Two types of companies recycle this material—companies that produce acid for consumption in their own operations and also recycle their own spent acid and companies that provide acid regeneration services to sulfuric acid users.

The petroleum refining industry was thought to be the leading source and consumer of recycled acid for use in its alkylation process. E.I. du Pont de Nemours and Co. built two new sulfuric acid regeneration plants during the year (North American Sulphur Review, 2006f).

Stocks

Yearend inventories held by recovered elemental sulfur producers increased to 221,000 t, 38% more than those of 2005 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 7-day supply compared with a 5-day supply in 2005, a 5-day supply in 2004, a 6-day supply in 2003, and a 6-day supply in 2002. Final stocks in 2006 represented 3.9% of the quantity held in inventories at the end of 1976 when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1978, p. 1296).

Prices

Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was estimated to be $32.85 per metric ton, which was 6.4% higher than that of 2005. The increased value reported by producers did not correlate well with prices recorded in trade publications.

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at $73.00 to $76.00 per metric ton. In March, prices decreased to $66.50 to $69.50 per ton and decreased again in October to $58.50 to $61.50 per ton and remained at that level through the remainder of the year.

Prices vary greatly on a regional basis. Tampa prices were usually the highest reported in the United States because of the large sulfur demand in the central Florida area. During 2006, U.S. west coast prices were varied from as high as $27 per ton to lower than $0, meaning that expenses were incurred to get the material to market. Nearly all the sulfur produced in this region is processed at forming plants, incurring substantial costs to make solid sulfur in acceptable forms that can be shipped overseas. The majority of west coast sulfur was shipped overseas. Global sulfur prices generally were higher than domestic prices in 2006.

Although not technically a price increase, fuel surcharges doubled for rail transport for sulfur during 2006, and the rental cost of sulfur railcars rose by 36% to $750 per month during 2006, increasing the cost of getting sulfur to market. Because these two factors significantly increased the cost of sulfur transportation and sulfur prices decreased during 2006, sulfur producers' made even less for the material they sold (Green Markets, 2006b).

Foreign Trade

Exports of elemental sulfur from the United States, including the U.S. Virgin Islands, were 7.2% lower in quantity than those of 2005, and 21% lower in value because the average unit value of export material decreased to $68.95 per metric ton (table 7). New sulfur-forming facilities on the U.S. Gulf Coast made their first offshore shipments in 2006. Brazil was the leading market for this material, followed by Morocco and Senegal (North American Sulphur Review, 2006f). As a result of new export facilities on the Gulf Coast, west coast exports were less dominant than in previous years. Exports from the west coast were 277,000 t, or 44% of total U.S. exports. Exports from the Gulf Coast were 246,000 t, or 39% of the U.S. total.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by more than 2.3 Mt. Recovered elemental sulfur from Canada, Mexico, and Venezuela delivered to U.S. terminals and consumers in the liquid phase furnished 99% of all U.S. sulfur import requirements. Total elemental sulfur imports were 4.6% higher in quantity, but lower prices for imported material resulted in the value being about the same as it was in 2005. Imports from Canada, mostly by rail, were estimated to be 6.3% higher in quantity, waterborne shipments from Mexico were 12% higher than those of 2005, and waterborne imports from Venezuela were estimated to have decreased by 12%. Canada was the source of an estimated 71% of elemental sulfur imports; Mexico, 16%; and Venezuela, 12% (table 9).

In addition to elemental sulfur, the United States also had significant trade in sulfuric acid. Sulfuric acid exports were 27% lower than those of 2005 (table 8). Acid imports were nearly 10 times greater than those of exports (tables 8, 10). Canada and Mexico were the sources of 90% of U.S. acid imports, most of which were probably byproduct acid from smelters. Shipments from Canada and some from Mexico came by rail, and the remainder of imports came primarily by ship from Chile and Europe. The tonnage of sulfuric acid imports was 9.5% less than that of 2005, and the value of imported sulfuric acid decreased by 26%.

World Review

The global sulfur industry remained divided into two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of either sulfur or pyrites (mostly naturally occurring iron sulfide) is based on the orderly mining of discrete deposits with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct; the quantity of output is subject to demand for the primary product irrespective of sulfur demand. Discretionary sources, once the primary sources of sulfur in all forms, represented 11% of the sulfur produced in all forms worldwide in 2006 (table 11).

Poland was the only country that produced more than 500,000 t of native sulfur by using either the Frasch or conventional mining methods (table 11). The Frasch process is the term for hot-water mining of native sulfur associated with the caprock of salt domes and in sedimentary deposits; in this mining method, the native sulfur is melted underground with superheated water and brought to the surface by compressed air. Small quantities of native sulfur were produced in Asia, Europe, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China was the only country of the top producers whose primary sulfur source was pyrites. China produced 84% of world pyrite production.

Of the 25 countries listed in table 11 that produced more than 500,000 t of sulfur, 18 obtained the majority of their production as recovered elemental sulfur. These 25 countries produced 92% of the total sulfur produced worldwide. The international sulfur trade was dominated by, in descending order of quantity exported, Canada, Russia, Saudi Arabia, the United Arab Emirates, Kazakhstan, Japan, and Iran; these countries exported more than 1 Mt of elemental sulfur each and accounted for almost 74% of total sulfur trade. The major sulfur importers were, in descending order, China, Morocco, the United States, Tunisia, India, and Brazil, all with imports of more than 1 Mt.

World production of sulfur was the same in 2006 as it was in 2005; consumption was thought to be slightly higher than in 2005, but slightly less than production, making 2006 the 15th consecutive year in which sulfur production exceeded consumption.

Prices in most of the world were thought to have averaged lower throughout the year than in the previous year. Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was slightly higher than that of 2005. Recovered elemental sulfur production was slightly lower, and byproduct sulfuric acid production increased slightly compared with that of 2005. Supplies of sulfur in all forms continued to exceed demand, although only slightly in 2006. Worldwide sulfur inventories edged higher; much of the inventory was stockpiled in Canada and Kazakhstan, although Canadian stocks actually declined owing to the strong international demand for sulfur. Globally, production of sulfur from pyrites was stable.

The European Parliament enacted new rules for marine fuels that were to be phased in beginning in May 2006. The sulfur content limit for marine fuels was reduced to 1.7% (from an average of 2.7% previously) for all ships in the Baltic Sea effective May 19, 2006, and for ships in the North Sea and the English Channel starting in fall 2007. Passenger vessels with regular routes between European ports must meet the earlier deadline, and ships operating on inland waterways and berthed in European Union (EU) ports will be restricted to fuels containing 0.1% sulfur starting January 1, 2010. These changes were expected to reduce sulfur dioxide emissions from ships by 500,000 t/yr. Results will be evaluated in 2008, and depending on the results, more restrictions may then be imposed if the emission reductions are not satisfactory or if the United Nations' Maritime Organization has been successful in implementing reduced sulfur provisions (Sulphur, 2005d). In most cases, ferry operators in Scandinavia and the Baltic Sea complied with MARPOL Annex VI, which was ratified in 2005, but low availability of 1.5% sulfur fuel at some Mediterranean ports limited compliance there (Sulphur, 2006d).

Canada.—With production of sulfur in all forms nearly identical to that of the United States in 2006, Canada's total production was slightly higher than it was in 2005. The majority of sulfur production came from natural gas plants in Alberta. Other sources were oil sands operations and oil refineries. Sulfur production from natural gas operations decreased by 3% from that of 2005, and sulfur production from oil sands increased by about 12%. These trends were expected to continue, with decreasing quantities of sulfur from natural gas production and increasing amounts from oil sands (North American Sulphur Review, 2006f).

Canada led the world in exports of elemental sulfur and stockpiled material. Canadian exports were 8.6 Mt, slightly less than those of 2005, much of it going to China (Stone, 2007). For the fourth consecutive year, strong demand prompted remelting of stocks in Canada. Monthly remelting averaged 100,000 t, totaling about 1.2 Mt for the year (North American Sulphur Review, 2007). With remelting from some stockpiles and limited accumulation at more remote operations, Canadian stocks decreased by about 600,000 t during the year (North American Sulphur Review, 2006f). At yearend, Canadian stocks were 12.1 Mt. Most stocks were at oil sands operations in northern Alberta, an area with limited infrastructure for getting the material to market (Stone, 2007).

Oil sands in Alberta hold a vast resource of hydrocarbon materials that rivals the reserves in the Middle East. Current technology defines reserves that are nearly equal to those of Saudi Arabia, but 80% of the resource is deemed unrecoverable. Advanced technology could improve recovery, giving Alberta the largest petroleum reserves in the world. Alberta oil sands contain bitumen, which is low-quality petroleum with up to 5% sulfur, which must be upgraded before it is processed in traditional oil refineries. By 2020, sulfur recovery at oil sands upgraders was expected to reach 20,000 metric tons per day (t/d), which is equivalent to 7.3 million metric tons per year (Mt/yr) (Clark, 2006).

Oil sands producers were considering strategies for getting sulfur produced at remote sites to markets. Options included building centralized forming facilities for the use of multiple sulfur producers, installing forming apparatus at individual oil sands operations, and railing molten sulfur to a port in British Columbia with facilities for forming and export (North American Sulphur Review, 2006b).

Stringent guidelines limiting sulfur emissions at gas processing plants in Alberta resulted in a 32% reduction of those emissions since the guidelines were enacted in 2000. The rules applied to new operations and older facilities that had previously not been required to meet newer environmental standards. A variety of strategies were adopted; 12 of the older plants installed new apparatus to reduce sulfur emissions, 8 were relicensed, and 5 were shut down (North American Sulphur Review, 2006d).

China.—China was the world's leading producer of pyrites, with 51% of the country's sulfur in all forms coming from that source. The country was also the leading sulfur importer, with 8.6 Mt in 2006, much of which was used to produce sulfuric acid consumed in the production of phosphate fertilizers.

China has become the second ranked global oil consumer, but its refineries were not equipped to process large quantities of high-sulfur crudes. More than a dozen refineries were being built or revamped to process sourer crudes by 2010. This was expected to result in a large increase of sulfur recovery when the plants are operational (Sulphur, 2006h).

Iran.—Completion of phases 4 and 5 of the South Pars and improvements at existing natural gas processing operations increased sulfur recovery in Iran, although future developments at South Pars may include reinjection of acid gases. Sulfur recovery could increase by 500,000 t/yr when the long-term project is completed (Sulphur, 2007b).

Kazakhstan.—Production at Tengizchevroil LLP (TCO) was expected to double to 2.4 Mt/yr in 2007. The company was increasing sulfur forming capacity. Blocked sulphur reached 9 Mt in 2006 with total stocks estimated to be 1.2 Mt, causing increased pressure from the Government to move the block. The remoteness of the operation, on the northeastern edge of the Caspian Sea, makes the logistics of shipping sulfur more complicated and expensive. Any sulfur exported from Kazakhstan to China must travel at least 6,000 kilometers. TCO has increased its offshore markets to include Argentina, Brazil, Egypt, India, Israel, Jordan, Morocco, Senegal, Spain, Tunisia, and Turkey (van Meurs, 2006).

Kuwait.—Kuwait National Petroleum Co. (KNPC) planned to build one new refinery, modernize two existing refineries, and close another. Total refining capacity was to go from 915,000 barrels per day to 1.4 million barrels per day by 2011. Refinery expansions may result in an additional 500,000 t/yr of sulfur production (Sulphur, 2007b).

Mexico.—Petróleos Mexicanos (Pemex), Mexico's national oil company was working to upgrade its refineries to produce low-sulfur gasoline and ULSD. The fuel-quality improvement project was expected to build 22 new sulfur recovery plants and improve 18 others. The sulfur content of gasoline would decline to 30 ppm from 500 ppm in large cities and 1,000 ppm in other areas. Sulfur in diesel will decrease to 15 ppm from 500 ppm. The ULSD was expected to be available in the northern border regions of Mexico starting in January 2007, in major cities in other regions in January 2009, and in other areas later in 2009 (Sulphur, 2006e).

Qatar.—Qatargas Operating Co. Ltd. was increasing its liquefied natural gas (LNG) facilities and Common Sulphur Project at Ras Laffan to handle a maximum of 12,000 t/d (4.4 Mt/yr) of sulfur. Sulfur production could expand by 1.5 Mt/yr (Sulphur, 2007b). Construction of several gas processing operations is expected to result in Qatar becoming one of the world's leading producers of recovered sulfur for export (Sulphur, 2006a).

Russia.—Russia's Astrakhangazprom, LLC was the world's leading sulfur-producing company. It produced sulfur at the Astrakhan gas processing plant from eight sulfur recovery plants, each with the capacity to produce about 80 metric tons per hour. Recent sulfur developments at Astrakhan have focused on improving the quality of the product through the installation of forming equipment to minimize the sales of crushed and broken sulfur, replacing it with pelletized sulfur with a low acidity level (Sulphur, 2005a).

Russia's Gazprom and Kazakhstan's Kazmunaigaz reached an agreement that natural gas produced at Kazakhstan's Karachaganak field would be processed at the Orenburg gas processing plant in Russia, which would be expanded to handle the additional throughput. Gazprom would have the rights to export the sulfur, although the natural gas would be returned to Kazakhstan. The expansion at Orenburg and the existing capacity at Astrakhan would make Gazprom a ranking sulfur producer and exporter (Sulphur, 2006c). Production at LLC OrenburgGazprom (OGP) was about 1.0 Mt in 2006, of which 600,000 t was marketed in molten form and the rest as formed sulfur. Production was expected to increase by at least 500,000 t/yr by about 2010 (van Meurs, 2006).

As has happened in much of the world, five old pyrites-burning sulfuric acid plants in Russia were being replaced by a total of four sulfur-burners. Two of the new units were in operation in 2006, one was scheduled for completion in 2007, and another at a later date. When all four new sulfuric acid plants are in operation, pyrite roasting will stop, and waste pyrite cinders will no longer be produced (Sulphur, 2006i).

Saudi Arabia.—Projects in Saudi Arabia hold the promise of increased sulfur production to be offset by increased consumption. Saudi Arabia expected to increase sulfur recovery when it builds new joint-venture refineries, expands capacity and modernizes equipment at existing refineries, and installs new gas processing facilities. Three new refineries were planned for Saudi Arabia in partnership with Western refining companies, and expansions at two existing refineries were underway. Sulfur recovery was expected to increase by 1.5 Mt/yr (Sulphur, 2007b). By 2010, sulfur recovery in Saudi Arabia could reach 4 Mt, an increase of more than 1 Mt from 2006 production (Sulphur, 2006b).

The Ma'aden phosphate project included mining and beneficiation in the northern part of the country, a rail line to carry the ore to a phosphoric acid plant, and a diammonium phosphate plant at Ras Az Zawr on the Persian (Arabian) Gulf. When completed, the phosphate operation was expected to consume a large portion of Saudi sulfur production. Phase I would require about 1.5 Mt/yr of sulfur to supply its sulfuric acid plants by about 2014, and another 1 Mt would be required for phase 2 sometime after that (Sulphur, 2006b).

United Arab Emirates.—Abu Dhabi Gas Liquifaction Co. Ltd. (Adgas) was working to expand its sulfur production capacity to 9 Mt/yr by 2012 from 2 Mt/yr in 2006 because expanded LNG projects would require it. Abu Dhabi Gas Industries Ltd.'s (Gasco's) operation at Habshan had the highest sulfur recovery capacity of any single facility in the world at 4,500 t/d (1.6 Mt/yr). The company was building a sulfur pipeline from Habshan to its Ruwais sulfur hub, at which sulfur recovered by Adgas and Gasco from onshore and offshore natural gas operations was formed and marketed. Previously, sulfur from Gasco's offshore facility had been transported to Ruwais via ship. Abu Dhabi Nation Oil Co. (Adnoc) handled sales and marketing for Adgas. Its primary markets were Asia, Africa, and the Middle East. China, India, Jordan, Morocco, Senegal, South Africa, and Tunisia bought Adnoc's formed sulfur products, and Indonesia received molten sulfur from Abu Dhabi (Sulphur, 2007a).

Sajaa Gas Private Limited Company (SajGas) was building a new gas processing plant in Sharjah, which would produce a relatively modest 120,000 t/yr of sulfur. Nearly 50% of the United Arab Emirate's gas deposits are very sour, with some containing up to 20% hydrogen sulfide, which must be removed from the gas product and recovered as elemental sulfur (Sulphur, 2007b).

Outlook

Although sulfur production decreased for the second consecutive year, the industry was expected to resume its trends toward increased production, slow growth in consumption, higher stocks, and expanded world trade. U.S. production from petroleum refineries took longer than expected to recover to pre-2005 levels, but increases were expected in the next few years as expansions, upgrades, and new facilities at existing refineries are completed. The expansions were enabling refiners to increase throughput of crude oil and to process higher sulfur crudes; additional sulfur production will be a byproduct of refining upgrades. Production from natural gas operations was expected remain about the same in 2007 after the steep decline in 2006 that resulted from decreased production in Wyoming. In 2006, 60% of all domestic gas-derived sulfur recovery was from Wyoming, down from 72% in 2005. Depletion at other fields in the United States as a natural function of long-term extraction of natural gas is likely to result in a further decrease of 100,000 t/yr from natural gas operations over time (D'Aquin, 2005). ConocoPhillips has the capacity to produce large quantities of sulfur at its Lost Cabin operation in Wyoming but had the option of storing excess production underground if the markets were not favorable for sales. Theoretically, this material would be available to meet future needs. In reality, however, it was more likely to represent an option for disposing of unwanted surplus material.

Worldwide recovered sulfur output is expected to increase significantly in the future. Sulfur surpluses were expected beginning in 2010 with acceleration thereafter as a result of increased production, especially from oil sands in Canada, natural gas in the Middle East, expanded oil and gas operations in Kazakhstan, and heavy-oil processors in Venezuela (Sulphur, 2005b).

Additional increases were expected to come from Russia's growth in sulfur recovery from natural gas and Asia's improved sulfur recovery at oil refineries. Refineries in developing countries are expected to improve environmental protection measures and, in the future, eventually approach the environmental standards of plants in Japan, North America, and Western Europe. An in-depth analysis conducted by Black & Veatch Corp., an international engineering, consulting and construction company, predicted that sulfur recovery from global petroleum refineries could reach 50 Mt/yr in 2025. Higher recovery will result from a number of factors, including higher refining rates, higher sulfur content in crude oil, and reduced sulfur emissions mandated by regulations (Sulphur, 2006j).

The world demand for natural gas is expected to maintain strong growth, and sulfur recovery from that sector will continue to increase. Future gas production, however, is likely to come from deeper, hotter, and more sour deposits that would result in even more excess sulfur production unless more efforts are made to develop new large-scale uses for sulfur. Other alternative technologies for reinjection and long-term storage to eliminate some of the excess sulfur supply will require further investigation to handle the quantity of surplus material anticipated (Hyne, 2000).

Byproduct sulfuric acid production was expected to remain relatively steady in the United States as long as copper smelters remain idle or no additional smelters close. With the copper industry's switch to lower cost production processes and offshore production, the four idle smelters may never reopen.

Worldwide, the outlook is different. Because copper production costs in some countries are lower than in the United States, acid production from those countries has increased, and continued increases are likely. Many copper producers have installed more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Byproduct sulfuric acid production was expected to increase to 70.3 Mt in 2014 from about 52 Mt in 2006. Worldwide, sulfur emissions at nonferrous smelters have declined as a result of improved sulfur recovery; increased byproduct acid production is likely to become more a function of metal demand than a function of improved recovery technology. One-half of the projected increase of byproduct acid production will likely be from smelters in China, with additional quantities from Chile and Peru, although production from all regions was expected to increase (Sulphur, 2005b).

Frasch sulfur and pyrites production, however, have little chance of significant long-term increases, although higher sulfur prices have resulted in temporary increases in pyrites production and consumption. Because of the continued growth of elemental sulfur recovery for environmental reasons rather than demand, discretionary sulfur has become increasingly less important as demonstrated by the decline of the Frasch sulfur industry. The Frasch process has become the high-cost process for sulfur production. Pyrites, with significant direct production costs, is an even higher cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output will probably show a steady decline. The decreases will be pronounced when large operations are closed outright for economic reasons, as was the case in 2000 and 2001.

Sulfur and sulfuric acid will continue to be important in agricultural and industrial applications, although consumption was expected to be less than production. Because sulfuric acid consumption for phosphate fertilizer production was expected to increase at a lower rate than some other uses, phosphate may become less dominant in sulfur consumption but remain the leading end use. Ore leaching likely will be the largest area of sulfur consumption growth (Sulphur, 2005b). World sulfur consumption of fertilizer was forecast to increase by 2.7% per year for the next 10 years; industrial consumption is expected to grow by 2.3% per year.

Use of sulfur directly or in compounds as fertilizer was expected to increase, but this use will be dependent on agricultural economies and increased acceptance of the need for sulfur in plant nutrition. If widespread use of plant nutrient sulfur is adopted, then sulfur consumption in that application could grow significantly; thus far, however, growth has been slow. The most significant expansions of phosphate fertilizer production were expected in China, Brazil, Egypt, Morocco, Saudi Arabia, and Tunisia (Sulphur, 2006j).

Industrial sulfur consumption has some prospects for growth, but not enough to consume all projected surplus production. Sulfur and sulfuric acid consumption for mining projects in Africa is expected to nearly double in the next few years, mostly for copper leach projects. New metal mining projects that will require sulfuric acid were recently completed, under development, or proposed in Botswana, Congo (Kinshasa), Madagascar, Malawi, Namibia, South Africa, and Zambia. Development was expected to be slow, however, because infrastructure will need to be improved to allow for achieving full potential in the region (Sulphur, 2006j).

Unless less traditional uses for elemental sulfur increase significantly, the oversupply situation will result in tremendous stockpiles accumulating around the world. In the 1970s and 1980s, research was conducted that showed the effectiveness of sulfur in several construction uses that held the promise of consuming huge quantities of sulfur in sulfur-extended asphalt and sulfur concretes. In many instances, these materials were found to be superior to the more conventional products, but their use so far has been very limited. When sulfur prices are relatively high, as they were in 2006, sulfur is less attractive for unconventional applications where low-cost raw materials are the important factor.

Although periods of tight supplies may take place periodically, the long-term worldwide oversupply situation is likely to continue. Unless measures are taken to use more sulfur, either voluntarily or through government mandate, large quantities of excess sulfur could be amassed in many areas of the world, including the United States.

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TABLE 1

SALIENT SULFUR STATISTICS[1]

(Thousand metric tons of sulfur content and thousand dollars unless otherwise specified)

	2002	2003	2004	2005	2006
United States:					
Quantity:					
Production:					
Frasch	--	--	--	--	--
Recovered[2]	8,500	8,910 r	9,380	8,790 r	8,390
Other	772	683	739	711	674
Total[e]	9,270	9,600	10,100	9,500 r	9,060
Shipments:					
Frasch	--	--	--	--	--
Recovered[2]	8,550 r	8,970 r	9,410	8,770 r	8,290
Other	772	725 r	739	711	674
Total	9,320 r	9,690 r	10,100	9,480 r	8,960
Exports:					
Elemental[3]	709	840	949	684	635
Sulfuric acid	48	67	67	110	79
Imports:					
Elemental	2,560	2,870 e	2,850 e	2,820 e	2,950 e
Sulfuric acid	346	297	784	877	793
Consumption, all forms[4]	11,500 r	11,900	12,800	12,400 r	12,000
Stocks, December 31, producer, recovered	181	206	185	160	221
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Frasch	--	--	--	--	--
Recovered[e, 2]	100,000	256,000	306,000	270,000	272,000
Other	35,500	34,000	61,100	80,200	64,700
Total	136,000	290,000	367,000	351,000	337,000
Exports, elemental[5]	43,100	54,400	63,300	55,200	43,800
Imports, elemental	26,800	70,600	76,800	70,500	70,400
Price, elemental, f.o.b. mine or plant[e] dollars per metric ton	11.82	28.70	32.62	30.88 r	32.85
World, production, all forms (including pyrites)	62,000 r	63,500 r	65,500 r	65,600 r	65,700

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

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

[2]Includes U.S. Virgin Islands.

[3]Includes exports from the U.S. Virgin Islands to foreign countries.

[4]Consumption is calculated as shipments minus exports plus imports.

[5]Includes value of exports from the U.S. Virgin Islands to foreign countries.

TABLE 2

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

	2005			2006		
		Shipments			Shipments	
State	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	277 [r]	280 [r]	9,420	245	245	9,580
California	1,080	1,040	26,500	1,140	1,090	20,700
Illinois	567	568	13,700	510	511	15,700
Louisiana	1,150	1,150	36,600	1,270	1,270	48,400
Michigan and Minnesota	35	35	974	36	37	1,060
New Mexico	32	32	(2)	30	30	113
Ohio	111	111	3,480	129	129	4,840
Texas	2,830	2,840	110,000	2,700	2,690	103,000
Washington	137	137	(2)	125	124	3,600
Wyoming	1,300	1,310	23,900	880	870	21,900
Other[3]	1,270 [r]	1,270 [r]	45,000 [r]	1,320	1,300	43,200
Total	8,790 [r]	8,770 [r]	270,000	8,380	8,290	272,000

[e]Estimated. [r]Revised.

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

[2]Some sulfur producers in this State incur expenses to make their products available to consumers.

[3]Includes Arkansas, Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Mississippi, Montana, New Jersey, North Dakota, Pennsylvania, Utah, Virginia, Wisconsin, and the U.S. Virgin Islands.

TABLE 3

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT[1]

(Thousand metric tons)

	2005		2006	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	234	235	229	227
Natural gas	19	18	42	42
Total	253	253	271	269
PAD 2:				
Petroleum and coke	1,040	1,040	1,030	1,030
Natural gas	36	36	40	40
Total	1,070	1,070	1,070	1,070
PAD 3:[2]				
Petroleum and coke	4,320	4,330	4,330	4,290
Natural gas	533 [r]	534 [r]	483	484
Total	4,850 [r]	4,860 [r]	4,820	4,780
PAD 4 and 5:				
Petroleum and coke	1,350	1,310	1,370	1,310
Natural gas	1,260	1,270	861	859
Total	2,610	2,580	2,230	2,170
Grand total	8,790 [r]	8,770 [r]	8,380	8,290
Of which:				
Petroleum and coke	6,940	6,910	6,960	6,870
Natural gas	1,850 [r]	1,850 [r]	1,430	1,430

[r]Revised.

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

[2]Includes the U.S. Virgin Islands.

TABLE 4

BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES[1, 2]

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2005	2006
Copper[3]	575	576
Zinc, lead, and molybdenum[4]	137	98
Total:		
Quantity	711	674
Value	80,200	64,700

[1]May include acid produced from imported raw materials.
[2]Data are rounded to no more than three significant digits, may not add to totals shown.
[3]Excludes acid made from pyrites concentrates.
[4]Excludes acid made from native sulfur.

TABLE 5

CONSUMPTION OF SULFUR IN THE UNITED STATES[1, 2, 3]

(Thousand metric tons)

	2005	2006
Elemental sulfur:		
Shipments[4]	8,770 r	8,290
Exports	684	635
Imports[e]	2,820	2,950
Total	10,900	10,600
Byproduct sulfuric acid:		
Shipments[4]	711	674
Exports[5]	110	79
Imports[5]	877	793
Total	1,480	1,390
Grand total	12,400 r	12,000

[e]Estimated. [r]Revised.
[1]Crude sulfur or sulfur content.
[2]Data are rounded to no more than three significant digits; may not add to totals shown.
[3]Consumption is calculated as shipments minus exports plus imports.
[4]Includes the U.S. Virgin Islands.
[5]May include sulfuric acid other than byproduct.

TABLE 6

SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE[1]

(Thousand metric tons of sulfur content)

SIC[3]	End use	Elemental sulfur[2] 2005	Elemental sulfur[2] 2006	Sulfuric acid (sulfur equivalent) 2005	Sulfuric acid (sulfur equivalent) 2006	Total 2005	Total 2006
102	Copper ores	--	--	395	327	395	327
1094	Uranium and vanadium ores	--	--	7	2	7	2
10	Other ores	--	--	53	47	53	47
26, 261	Pulpmills and paper products	W	W	267	246	267	246
28, 285, 286, 2816	Inorganic pigments, paints, and allied products, industrial organic chemicals, other chemical products[4]	W	W	312	426	312	426
281	Other inorganic chemicals	W	89	109	42	109	131
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	64	250	64	250
2823	Cellulosic fibers including rayon	--	--	--	156	--	156
283	Drugs	--	--	1	--	1	--
284	Soaps and detergents	--	W	7	3	7	3
286	Industrial organic chemicals	--	--	17	88	17	88
2873	Nitrogenous fertilizers	--	--	214	25	214	25
2874	Phosphatic fertilizers	--	--	7,000	6,220	7,000	6,220
2879	Pesticides	--	--	15	2	15	2
287	Other agricultural chemicals	1,770	2,010	48	12	1,810	2,020
2892	Explosives	--	--	10	8	10	8
2899	Water-treating compounds	--	--	67	64	67	64
28	Other chemical products	--	--	290	334	290	334
29, 291	Petroleum refining and other petroleum and coal products	3,590	3,120	188	262	3,780	3,380
30	Rubber and miscellaneous plastic products	W	W	3	3	3	3
331	Steel pickling	--	--	52	13	52	13
333	Nonferrous metals	--	--	4	1	4	1
33	Other primary metals	--	--	10	38	10	38
3691	Storage batteries (acid)	--	--	16	23	16	23
	Exported sulfuric acid	--	--	26	22	26	22
	Total identified	5,360	5,220	9,180	8,610	14,500	13,800
	Unidentified	910 r	990	503	132	1,410 r	1,120
	Grand total	6,270 r	6,210	9,680	8,750	16,000 r	15,000

W Withheld to avoid disclosing company proprietary data; included with "Unidentified." r Revised. -- Zero.

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

[2]Does not include elemental sulfur used for production of sulfuric acid.

[3]Standard industrial classification.

[4]No elemental sulfur was used in inorganic pigments, paints, and allied products.

TABLE 7

U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY[1, 2]

(Thousand metric tons and thousand dollars)

	2005		2006	
Country	Quantity	Value	Quantity	Value
Argentina	59	3,000	9	468
Brazil	165	11,800	184	10,800
Canada	110	8,610	97	7,570
China	248	20,200	95	8,240
Mexico	31	1,950	40	2,010
Morocco	15	491	121	4,620
Senegal	18	1,690	57	2,700
Switzerland	12	608	--	--
Other	26 r	6,930 r	32	7,350
Total	684	55,200	635	43,800

[r]Revised. -- Zero.

[1]Includes exports from the U.S. Virgin Islands.

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

Source: U.S. Census Bureau.

TABLE 8

U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY[1]

	2005		2006	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	--	--	7,270	$297
Aruba	1,740	$399	1,630	399
Brazil	49,400	2,040	11,800	510
Canada	101,000	8,120	94,900	8,350
China	2,320	449	836	186
Dominican Republic	6,970	562	3,510	510
Germany	6,530	1,240	864	207
Ireland	2,360	1,190	3,500	1,170
Israel	257	355	162	215
Italy	2,810	322	--	--
Jamaica	(2)	47	3,130	239
Japan	3,920	623	54	83
Korea, Republic of	3,200	436	109	436
Malaysia	6,700	954	875	106
Mexico	3,000	683	6,550	1,320
Netherlands Antilles	12,000	633	4,480	257
Peru	(2)	3	14,100	1,630
Saudi Arabia	375	1,010	1,440	306
Singapore	11,600	1,600	4,440	548
Taiwan	15,700	2,190	318	229
Trinidad and Tobago	18,000	908	22,100	1,000
United Kingdom	371	333	908	561
Venezuela	86,500	4,570	62,700	2,800
Other	3,130	804 r	2,650	453
Total	338,000	29,500	248,000	21,800

[r]Revised. -- Zero.

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

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2005		2006	
Country	Quantity	Value[2]	Quantity	Value[2]
Canada	1,970 [e]	33,500	2,100 [e]	33,000
Mexico	427	18,600	476	20,100
Venezuela	409 [e]	16,800	359 [e]	15,100
Other	14 [e]	1,600	19 [e]	2,170
Total	2,820 [e]	70,500	2,950 [e]	70,400

[e]Estimated.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared customs valuation.

Source: U.S. Census Bureau, PentaSul North American and Sulphur Service as adjusted by the U.S. Geological Survey.

TABLE 10
U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY[1]

	2005		2006	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	2,010,000	$89,400	1,980,000	$79,200
Chile	100,000	5,380	15,800	215
Germany	22,300	678	58,000	1,400
Mexico	398,000	9,440	198,000	4,810
Sweden	19,700	811	39,900	1,070
Other	136,000 [r]	16,600 [r]	135,000	3,430
Total	2,680,000	122,000	2,430,000	90,100

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

TABLE 11

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	2002	2003	2004	2005	2006
Australia, byproduct:[e]					
Metallurgy	899	863	870 [r]	880 [r]	880
Petroleum	60	60	60	60	61
Total	959	923	930 [r]	940 [r]	941
Canada, byproduct:					
Metallurgy	1,109	992	1,105 [r]	1,058 [r]	1,161 [p]
Natural gas, petroleum, tar sands	7,816	8,036	7,996 [r]	7,915 [r]	7,886 [p]
Total	8,925	9,028	9,101 [r]	8,973	9,047 [p]
Chile, byproduct, metallurgy[e]	1,275 [4]	1,430	1,510	969 [r, 4]	1,000
China:[e]					
Elemental	540	700	820	900	920
Pyrites	3,240	3,400	3,730	4,010	4,100
Byproduct, metallurgy	2,200	2,400	2,600	2,800	3,000
Total	5,980	6,500	7,150	7,710	8,020
Finland:[e]					
Pyrites	359	341	336	270 [r]	250
Byproduct:					
Metallurgy	308	305	301	300	300
Petroleum	55	60	65	70	65
Total	722	706	702	640 [r]	615
France, byproduct:[e]					
Natural gas and petroleum	796 [r, 4]	710 [r, 4]	698 [r, 4]	750	750
Unspecified	229	196	196	195	195
Total	1,030 [r]	906 [r]	894 [r]	945	945
Germany:					
Unspecified, marketable	-- [r]	-- [r]	-- [r]	-- [r]	--
Byproduct:					
Metallurgy	754	701	591	600 [e]	600 [e]
Natural gas and petroleum	1,745	1,661	1,503 [r]	1,585 [r]	1,686
Total	2,499 [r]	2,362 [r]	2,094 [r]	2,185 [r]	2,286
India:[e]					
Pyrites	32	32	32	32	32
Byproduct:					
Metallurgy	458	539	539	580	600
Natural gas and petroleum	371	451	501	520	540
Total	861	1,020	1,070	1,130	1,170
Iran, byproduct:[e]					
Metallurgy	50	50	60	60	65
Natural gas and petroleum	1,200 [4]	1,310	1,400	1,400	1,400
Total	1,250	1,360	1,460	1,460	1,465
Italy, byproduct:[e]					
Metallurgy	142	127	113	115	100
Petroleum	560	565	575	570	550
Total	702	692	688	685	650
Japan, byproduct:					
Metallurgy	1,326	1,281	1,263	1,284 [r]	1,350 [e]
Petroleum	1,865	1,951	1,895	1,972 [r]	1,980 [e]
Total	3,191	3,232	3,158	3,256 [r]	3,330 [e]
Kazakhstan, byproduct:[e]					
Metallurgy	260	325	325	325	300
Natural gas and petroleum	1,600	1,600	1,650	1,700	1,700
Total	1,860	1,930	1,980	2,030	2,000

See footnotes at end of table.

TABLE 11—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	2002	2003	2004	2005	2006
Korea, Republic of, byproduct:[e]					
Metallurgy	737	797	796	800	800
Petroleum	687	757	879	885	890
Total	1,420	1,550	1,680	1,690	1,690
Kuwait, byproduct, natural gas and petroleum[e]	634	714	682	700	650
Mexico, byproduct:					
Metallurgy[e]	588	539	703	700	700
Natural gas and petroleum	877	1,052	1,122	1,017	1,074
Total	1,465	1,591	1,825	1,717	1,774
Netherlands, byproduct:[e]					
Metallurgy	124	131	137	135	130
Petroleum	373	408	410	400	400
Total	497	539	547	535	530
Poland:[e, 5]					
Frasch	760 [4]	762	821 [r]	802 [r]	800
Byproduct:					
Metallurgy	276	294	290	250 [r]	250
Petroleum	180 [4]	180	190	190	190
Total	1,220	1,240	1,300 [r]	1,240 [r]	1,240
Russia:[e, 6]					
Native	50	50	50	50	50
Pyrites	350	350	300	300	300
Byproduct:					
Metallurgy	500	520	570	600	650
Natural gas	5,600	5,800	6,000	6,000	6,000
Total	6,500	6,720	6,920	6,950	7,000
Saudi Arabia, byproduct, all sources[e]	2,360	2,180	2,249 [r, 4]	2,717 [r, 4]	2,800
South Africa:					
Pyrites, S content, from gold mines	183	176	165	133	68 [p]
Byproduct:					
Metallurgy, copper, platinum, zinc plants	179 [e]	174	180	220 [r]	200 [e]
Petroleum	170	264	288	422 [r]	375 [e]
Total	532	614	633	776 [r]	643
Spain, byproduct:[e]					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	544	500 [r]	500 [r]	500 [r]	500
Petroleum	140	150 [r]	150 [r]	150 [r]	150
Total	685	651 [r]	651 [r]	651 [r]	651
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,900	1,900	1,930	1,950	1,950
United States, byproduct:					
Metallurgy	772	683	739	711	674
Natural gas	1,760	1,940	1,990	1,850 [r]	1,430
Petroleum	6,750	6,970	7,390	6,940	6,960
Total	9,270	9,600	10,100	9,500 [r]	9,060
Uzbekistan, byproduct:[e]					
Metallurgy	170	170	170	170	170
Natural gas and petroleum	350	350	350	350	350
Total	520	520	520	520	520
Venezuela, byproduct, natural gas and petroleum[e]	570 [4]	560	800	800	800

See footnotes at end of table.

TABLE 11—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	2002	2003	2004	2005	2006
Other[e]	5,150 r	5,070 r	4,940 r	4,950 r	4,970
Of which:					
Frasch	23	19	20	20	20
Native[7]	524 r	302 r	275 r	241 r	242
Pyrites	159 r	170 r	167 r	161 r	152
Unspecified	1,070 r	1,110 r	1,130 r	1,170 r	1,150
Byproduct:					
Metallurgy	1,340 r	1,400 r	1,160 r	1,180 r	1,200
Natural gas	251 r	301 r	361 r	361 r	361
Natural gas and petroleum, undifferentiated	513 r	479 r	496 r	495 r	496
Petroleum	1,270 r	1,280 r	1,330 r	1,320 r	1,350
Grand total	62,000 r	63,500 r	65,500 r	65,600 r	65,700
Of which:					
Frasch	783	781	841 r	822 r	820
Native[7]	1,110 r	1,050 r	1,140 r	1,190 r	1,210
Pyrites	4,320 r	4,470 r	4,730 r	4,910 r	4,900
Unspecified	3,660 r	3,490 r	3,570 r	4,080 r	4,150
Byproduct:					
Coal, lignite, gasification[e]	1	1	1	1	1
Metallurgy	14,000	14,200 r	14,500 r	14,200 r	14,600
Natural gas	7,610	8,040 r	8,350 r	8,210 r	7,790
Natural gas, petroleum, tar sands, undifferentiated	18,400 r	18,800 r	19,100 r	19,200 r	19,300
Petroleum	12,100 r	12,600 r	13,200 r	13,000 r	13,000

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

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

[2]Table includes data available through July 17, 2007.

[3]The term "source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: Frasch recovery; native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); pyrites (whether or not the sulfur is recovered in the elemental form or as acid); byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations, including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and recovery from processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded because to include it would result in double counting. Production of Frasch sulfur, other native sulfur, pyrite-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which is not the original source country of the crude product from which the sulfur is extracted.

[4]Reported figure.

[5]Government of Poland sources report total Frasch- and native-mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

[6]Sulfur is thought to be produced from Frasch and as a petroleum byproduct; however, information is inadequate to formulate estimates.

[7]Includes "China, elemental."