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SULFUR [ADVANCE RELEASE]

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SULFUR

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In 2008, the upward climb of sulfur prices, which began in 2007, continued. Strong international demand and lower than expected production in some regions resulted in a perceived shortage of material in the global market. Booming demand for sulfur for fertilizer manufacturing around the world, with especially strong demand in China and India, resulted in the continued run-up in prices that peaked in July and August. From that point, prices began a downward trend that was steeper than the increase, plunging to negative values in some markets by yearend.

The United States was once again the global leader in sulfur production, with Canadian sulfur production slightly less than United States production. 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.

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; 32.4 million metric tons (Mt), which is equivalent to about 10.6 Mt of elemental sulfur, was produced in 2008, 10% less than in 2007 (U.S. Census Bureau, 2009).

In 2008, domestic production of sulfur in all forms was 4% higher than 2007; shipments of sulfur in all forms increased by 3%. Elemental sulfur recovered at petroleum refineries was 5% higher than it was in 2007, and sulfur recovered from natural gas operations increased by 3%, the first increase from that source since 1998. Producers' stocks increased by 13%, representing about 2% of shipments. Byproduct sulfuric acid production and shipments declined by 8%. Apparent consumption increased by 10%. Imports increased by 24%, mostly as the result of a surge of sulfuric acid imports, and exports remained about the same. The average unit value was eight times higher for 2008 in the United States, resulting in the value of elemental sulfur shipments increasing by an astounding 600% compared with the 2007 value of shipments. The total value of byproduct sulfuric acid shipments more than doubled, even though the quantity of shipments decreased (table 1).

Worldwide, compliance with environmental regulations contributed to sulfur recovery, with a slight increase in sulfur production. Recovered elemental sulfur is produced primarily during the processing of natural gas and crude petroleum. Estimated worldwide production of native (naturally occurring elemental) sulfur decreased by 4%. In the few countries where pyrites remain an important raw material for sulfuric acid production, strong demand and high sulfur prices resulted in a slight increase in sulfur production from pyrites.

Since 2003, between 82% and 84% of the world's sulfur production as elemental sulfur and byproduct sulfuric acid came from recovered sources. Some sources of sulfur were unspecified, which means that the material could be, and likely was, elemental sulfur 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 thought to be higher than it was in 2007; typically, about 50% is used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur decreased by about 6% from the levels reported in 2007. Worldwide inventories of elemental sulfur declined.

Legislation and Government Programs

Negotiations had been ongoing for many years on how to limit sulfur dioxide emissions from ocean-going vessels. One proposal was to limit the sulfur content of fuels used in these vessels via changes to annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). Near yearend 2008, the International Maritime Organization (IMO) ratified changes that reduced the allowable sulfur content of marine fuels (also known as bunker fuels), limiting sulfur content to 3.5% from 4.5% starting in 2012. Further reductions were set to limit sulfur content to 0.5% by 2020. Lower sulfur limits applied for designated "emission control areas" (ECAs). In 2010, ECA limits were to be 1.0% sulfur, declining to 0.1% in 2015. These reductions were part of a series of reduced sulfur limits in different types of fuels. Most nations have independently set sulfur limits for finished petroleum products starting with gasoline, followed by on-road and off-road diesel. Other fuel types that were expected to be facing the same type of scrutiny were home heating oil and jet fuel. Reducing the allowable sulfur in marine fuels was expected to result in tremendous additional quantities of recovered sulfur. From the estimated 270 Mt of bunker fuels that was used in global shipping in 2006, as much as 9.5 Mt of sulfur could be recovered (Sulphur, 2009).

California was drafting marine diesel rules that were more stringent than those issued by the IMO. The State issued final rules for comment limiting the sulfur content allowable in fuels used in ocean-going vessels that operated on California internal waters, ports, and within 24 miles of the California coast. The sulfur content in fuels used for auxiliary diesel engines, main engines, and auxiliary boilers was limited to 1.5% sulfur for marine gas oil (MGO) and 0.5% sulfur for marine diesel oil (MDO) beginning on July 1, 2009. Effective January 1, 2012, the sulfur content of those fuels was to be limited to 0.1% for MGO and MDO (California Code of Regulations, 2008, p. 10). The California regulations were expected to cut sulfur emissions from ships in the region by 80% through 2012 and 95% beginning in 2012. Approximately 2,000 ocean-going vessels that visit California ports annually were affected by this regulation (Sulphur, 2008c).

Production

Recovered Elemental Sulfur.—U.S. production statistics were collected on a monthly basis and published in the U.S. Geological Survey (USGS) monthly sulfur Mineral Industry Surveys. All 101 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2008, production was 5% higher than that of 2007, and shipments were 4% higher. Because of the tremendous price increase for elemental sulfur during the year, the value of shipments was seven times that of 2007. Although U.S petroleum refineries operated at generally high rates, accidents, technical problems, and especially weather emergencies at a few of refineries limited the amount of sulfur that could be recovered.

Two major hurricanes struck in the Gulf Coast during 2008 that affected sulfur production at refinery operations in the region. On September 1, 2008, Hurricane Gustav made landfall near Morgan City, LA. In advance of Gustav, 13 refineries along the Gulf of Mexico shut down to prepare for the hurricane, and another 10 refineries reduced operations. Recovery began almost immediately, and by September 9, all the refineries had begun their startup, except for one in Louisiana. On September 12, some of the same refineries began to shut down in preparation for the arrival of Hurricane Ike, which made landfall near Galveston, TX, on September 13. A total of 15 refineries in Louisiana and Texas shut down and an additional 9 were operating at reduced rates. At that point, approximately 22% of U.S. refinery capacity and a similar percentage of sulfur recovery capacity was curtailed. Once again, damage to refineries was relatively minor, but power outages slowed the recovery efforts. Even when refineries experience no significant damage, it can take a week or more for a refinery to return to normal operation. As a result of the storms, a significant percentage of domestic refinery capacity, and thus sulfur recovery capacity, was idle during much of September. Most of the operations were returning to normal by the end of the month (U.S. Energy Information Administration, 2008a–d). Refineries in Beaumont and Port Arthur, TX, experienced the most downtime. Sulfur shipping companies felt more of an impact from the storm, with damage to rail, storage, and port facilities in Galveston and Beaumont, but shipping too was mostly back to normal by the end of September (North America Sulphur Review, 2008b).

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 36 companies at 100 plants in 26 States and 1 plant in the U.S. Virgin Islands. The size of the sulfur recovery operations varied greatly from plants producing more than 500,000 metric tons per year (t/yr) to others producing less than 500 t/yr. Of all the sulfur operations canvassed, 29 produced more than 100,000 metric tons (t) of elemental sulfur in 2008, 20 produced between 50,000 and 100,000 t, 28 produced between 10,000 and 50,000 t, and 24 plants produced less than 10,000 t. By source, 85% 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, in descending order of production, were Valero Energy Corp., Exxon Mobil Corp., Shell Oil Co. (including its joint ventures with Petróleos Mexicanos and Saudi Refining, Inc.), Chevron Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), and BP p.l.c.. The 52 plants owned by these companies accounted for 67% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2008, 5 of the 20 largest oil refineries in the world, in terms of crude processing capacity, were in the United States. In descending order of capacity, they were ExxonMobil's Baytown, TX, and Baton Rouge, LA, refineries; Hovensa L.L.C.'s [Hess Corp.'s joint venture with Petróleos de Venezuela S.A. (PdVSA)] St. Croix, U.S. Virgin Islands refinery; BP's Texas City, TX, refinery; and Citgo Petroleum Corp.'s Lake Charles, LA, refinery (Oil & Gas Journal, 2008b). The capacity to process large quantities of crude oil does not necessarily mean that refineries recover large quantities of sulfur, but all these refineries were major producers of recovered sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the types of crude oil that were refined at the specific refineries. Major refineries that process low-sulfur crude oils may have relatively low sulfur production. According to Oil & Gas Journal (2008a), the United States operated 20% of world refining capacity, but almost 40% of sulfur recovery capacity at refineries.

According to data from the National Petrochemical and Refiners Association, U.S. refining capacity rose by more than 5% from 2003 through 2008 and by more than 8% from 1999 through 2008, without building any new refineries and with a few small operations closing. In 2008, U.S. refinery capacity was 18 million barrels per day (North America Sulphur Review, 2008d). Although this information did not specifically mention sulfur capacity expansion, any such expansions would likely include increased sulfur recovery facilities, probably proportionally higher than the increases in throughput capacity.

During 2008, expansion projects were underway or in the planning stages at 16 refineries in the United States. In addition to increasing throughput capacity at the operations, upgrades were intended to increase the existing refineries' capability to process low-quality, high-sulfur crudes, such as those from Canadian oil sands, Saudi Arabia, and Venezuela. Oil sands producers were partners in some of the projects, as part of a strategy to ensure outlets for future oil sands production. Some of the projects were beginning to experience delays in the permitting process as concerns were raised about the environmental impact of the expansions, with proposals to limit to the maximum sulfur content of crude that would be allowed. Some upgrades were completed in 2008, but most were expected to be completed between 2011 and 2013 (North America Sulphur Review, 2008g). One of the projects included plans to increase capacity of a crude oil pipeline system to transport Alberta sour crudes to Gulf Coast refineries, contingent on regulatory approvals (North America Sulphur Review, 2008c).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 8% of the total domestic production of sulfur in all forms and totaled the equivalent of 753,000 t of elemental sulfur. The portion of total sulfur product represented by byproduct sulfuric acid and the total quantity produced decreased by 8% as the result of decreased copper smelter production (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 byproduct sulfuric acid plants, in terms of size and capacity, were associated with copper smelters and accounted for 87% of the byproduct sulfuric acid output. The copper producers—Asarco LLC, Kennecott Utah Copper Corp., and Freeport McMoRan Copper & Gold Inc.—each operated a sulfuric acid plant at its primary copper smelter.

Consumption

Apparent domestic consumption of sulfur in all forms was 10% higher than that of 2007 (table 5). Of the sulfur consumed, 64% was obtained from domestic sources as elemental sulfur (59%) and byproduct acid (5%) compared with 68% in 2007, 69% in 2006, 70% in 2005, and 72% in 2004. The remaining 36% was supplied by imports of recovered elemental sulfur (23%) and sulfuric acid (13%). 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 60% of reported consumption with an identified end use. Although reported as elemental sulfur consumption in table 6, 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 to produce sulfuric acid to 83% of the total sulfur consumption. Some identified sulfur end uses were included in the “Unidentified” category because these data were proprietary. Data collected from companies that did not identify shipments 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 8%, and total reported sulfur consumption decreased by 3%. These reported decreases in consumption can be attributed in large part to the 10% decrease in sulfuric acid consumed in phosphate fertilizer applications. 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 6% to 7.84 Mt compared with 8.34 Mt in 2007 because of decreased production of phosphate fertilizers. Based on export data reported by the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased by 10% to 4.4 Mt. More than 50% of domestic fertilizer production typically is exported, as was the case in 2008.

The second ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported that the consumption of sulfur in that end use was the same as that in 2007. Demand for sulfuric acid in copper ore leaching, which was the third ranked end use, increased by 5%.

The U.S. Census Bureau (2009) also reported that 2.4 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.

Stocks

Yearend inventories held by recovered elemental sulfur producers increased to 211,000 t, 13% more than those of 2007 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 6-day supply, the same as in 2007, compared with a 7-day supply in 2006, and a 5-day supply in 2005 and 2004 each. Final stocks in 2008 represented 4% of the quantity held in inventories at the end of 1976, when sulfur stocks peaked at 5.56 Mt, a 7.4-month supply at that time (Shelton, 1978, p. 1296). When the United States mined large quantities of sulfur, as in 1976, mining companies had the capacity to store large quantities. When mining ceased in 2000, storage capacity declined significantly. Since that time, stocks have been relatively low because recovered sulfur producers have very little room for stocks.

Prices

As mentioned earlier in this report, sulfur prices were the big story of the year. Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was estimated to be $262.32 per metric ton, which was an astounding 700% higher than that of 2007. The increased value reported by producers correlated with the trends in prices recorded in trade publications. Prior to 2008, the highest average value of shipments was reported for 1981, when it was $111.48 per ton (Morse and Shelton, 1982, p. 807).

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at $110.50 to $113.50 per ton. Later in January, prices increased to $250.50 to $253.50 per ton. In April, prices rose again to $450.50 to $453.50 per ton and rose further in August to $615.50 to $618.50 per ton. They remained at that level until October when they began a steep decline to $150 per ton. Although the Tampa contract price remained at that level through the end of 2008, further declines were expected in 2009.

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 2008, U.S. west coast prices varied from less than $0 per ton to $590 per ton. When published prices are less than $0 per ton, expenses are incurred in order to get the material to market. Nearly all the sulfur produced in some regions, such as the west coast, is processed at forming plants, incurring substantial costs to make solid sulfur in acceptable forms to be shipped overseas. The majority of west coast sulfur was shipped overseas. Global sulfur prices generally were higher than domestic prices in 2008.

Although not a traditionally dominant factor in the sulfur market, Abu Dhabi National Oil Co.'s (ADNOC) monthly contract price became the bellwether of sulfur pricing during 2008. Although prices varied by location, provider, and type, the ADNOC price became a recognized indicator of sulfur price trends. The ADNOC contract price increased throughout the first 6 months of the year and peaked at $820 per ton in July (North America Sulphur Review, 2008e). In October, the ADNOC had declined to $200 per ton, was not published for November, and in December, fell to $50 per ton (North America Sulphur Review, 2008f). The price increases for about 18 months beginning in 2007 were unprecedented, but the decline was even more precipitous.

Foreign Trade

Strong international demand and high prices during much of the year resulted in exports of elemental sulfur from the United States, including the U.S. Virgin Islands, increasing by 3% in quantity and by 220% in value compared with those of 2007. The average unit value of export material was $285 per ton, an increase of 210% from $92 in 2007 (table 7). The leading destination for this material was China, followed, in descending quantity, by Brazil, Mexico, and Canada. Export facilities on the Gulf Coast that began shipping in 2006 have become a significant source for exported sulfur. Exports from the West Coast were 535,000 t, or 56% of total U.S. exports. Exports from the Gulf Coast were 260,000 t, or 27% of the U.S. total.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by about 2 Mt. Recovered elemental sulfur from Canada, Mexico, and Venezuela delivered to U.S. terminals and consumers in the liquid phase furnished almost 100% of U.S. sulfur import requirements. Total elemental sulfur imports were about the same in quantity as those of 2007, but higher prices for imported material resulted in the value being nearly 10 times what was in 2007. Imports from Canada, mostly by rail, were estimated to be 4% higher than those of 2007, waterborne shipments from Mexico were 14% lower, and waterborne imports from Venezuela were estimated to have decreased by 11%. Canada was the source of an estimated 73% of elemental sulfur imports, and Mexico and Venezuela, 12% each (table 9).

In addition to elemental sulfur, the United States had significant trade in sulfuric acid. Sulfuric acid exports were 22% lower than those of 2007 (table 8). Acid imports were about 13 times greater than exports (tables 8, 10). Canada and Mexico were the sources of 76% of acid imported into the United States, most of which was 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 Asia and Europe. The tonnage of sulfuric acid imports was about 34% more than that of 2007, and the value of imported sulfuric acid increased by almost 310%.

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 and environmental regulations that limit atmospheric emissions of sulfur compounds irrespective of sulfur demand. Discretionary sources, once the primary sources of sulfur in all forms, represented 10% of the sulfur produced in all forms worldwide in 2008 (table 11).

Poland was the only country that produced more than 500,000 t of native sulfur by using either the Frasch process 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. The United States, where the Frasch process was developed early in the 20th century, was the leading producer of Frasch sulfur until 2000. 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 87% 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 93% of the total sulfur produced worldwide. In 2008, 28 Mt of elemental sulfur was traded globally. The leading exporters, in decreasing order of tonnage, were Canada, Russia, Saudi Arabia, Kazakhstan, the United Arab Emirates, the Republic of Korea, the United States, and Iran, all with more than 1 Mt of exports. The leading importer was China, by far, followed by, in decreasing order of tonnage, the United States, Morocco, Brazil, Tunisia, and India. All of the top importing countries had large phosphate fertilizer industries (International Fertilizer Industry Association, 2010).

After 15 years of sulfur surpluses, significantly increased demand in China and India resulted in supply deficits in 2007 and 2008, resulting in the record-high prices during 2008, in July and August. Prices declined dramatically, however, through the last few months of 2008. International prices averaged higher than those in the United States. Although actual production was closely balanced with consumption during the first 7 months of 2008, the remote location of some producers kept that material from the market, inducing the drawdown of more accessible stockpiles.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was about 4% lower than that of 2007. Recovered elemental sulfur production and byproduct sulfuric acid production increased slightly compared with those of 2007. For the second consecutive year, available supplies of sulfur in all forms were less than consumption after several years of sulfur surpluses. Stocks in Canada and Kazakhstan declined owing to the strong international demand for sulfur. Globally, production of sulfur from pyrites increased slightly, mostly as a result of the strong demand for sulfur in all forms that drove prices up, making pyrites more attractive as a substitute for elemental sulfur for producing sulfuric acid. With sulfur prices as high as they were in 2008, sulfuric acid production from pyrites became a more attractive alternative for elemental sulfur. The environmental remediation costs of pyrites were less onerous when the price for sulfur more than made up for the additional costs necessitated by using the less environmentally friendly raw material.

Canada.—Ranked second in the world in sulfur production, Canada was the leading sulfur and sulfuric acid exporter. In 2008, sulfur production in Canada was 6% higher than it was in 2007. About two-thirds of Canadian sulfur is recovered at natural gas and oil sands operations in Alberta, with some recovered from gas in British Columbia and from oil refineries in other parts of the country. Sulfur recovery from natural gas has declined for several years, but increased sulfur production from oil sands offset that, and this trend was expected to continue. Although anticipated, the decline of sulfur production at Canadian natural gas operations fell at a higher rate than expected, at about 7% per year in 2007 and 2008, with expectations of this rate continuing in the future (North America Sulphur Review, 2008a). Significant increases in production from oil sands operations and minor increases at refineries were expected. Canada was likely to remain a leader in global sulfur production. Byproduct acid production was expected to remain relatively stable (Stone, 2009).

A report from Alberta's Energy Resources Conservation Board (ERCB) published in 2008 showed that sulfur emissions in 2007 from Alberta's natural gas processing plants declined by 45% from levels in 2000 and 17% from those of 2006. Sulfur emissions declined as the result of improved sulfur recovery technology at the plants and because gas production had declined as resources have become depleted. Although sulfur recovery increased as a percentage of gas processing, total sulfur declined during the same period because of lower gas processing volumes (Sulphur, 2008a).

An estimated 300,000 t of sulfur was remelted from stockpiles in 2008. Stocks decreased to about 11.5 Mt in Alberta in 2008, more than 8 Mt of which was stored at Syncrude Canada Ltd.'s Fort McMurray, Alberta, oil sands operation. Fort McMurray is so remote that transporting the sulfur to market is extremely difficult and expensive (Stone, 2009).

Oil sands development was one of the fastest growing industries in Canada. Expansions at oil sands operations were expected to add an additional 3.6 Mt of sulfur production within 10 years. By 2015, sulfur production from Canadian oil sands was expected to represent 8% of annual global sulfur production (Sulphur, 2007). Continued focus on greenhouse gas emissions from oil sands operations and other environmental scrutiny, however, may limit development of oil sands and direct investment dollars elsewhere. Estimates of the cost of production suggest that a price of $70 per barrel of oil is necessary for oil sands to be profitable. If national and/or provincial carbon taxes, which have been discussed for Canada and Alberta, were put into place, the cost of oil sands production could become too high. In addition to relatively high carbon dioxide emissions related to oil sands operations compared with those from other petroleum sources, concerns about tailings ponds and land restoration contributed to negative perceptions of oil sands development (Park, 2008a).

The Athabasca oil sands are a mixture of sand, water, clay, and bitumen, a naturally occurring viscous mixture of heavy hydrocarbons. Because of its complexity, bitumen was difficult or impossible to refine at most oil refineries. It was upgraded to a light-oil equivalent before further refining or was processed at facilities specifically designed for processing bitumen. Oil sands with more than 10% bitumen were considered rich; those with less than 7% bitumen were not economically attractive (Oil & Gas Journal, 1999). Bitumen contains approximately 5% sulfur. On average, it takes about 1 t of bitumen to produce 1 barrel of oil (Stone, 2007).

The global economic downturn that became evident late in the year had a major negative impact on Canadian oil sands projects. Starting in November, plans were announced to delay or reconsider several development and expansion projects. Oil sands operations require tremendous capital to develop, and only high oil prices allow them to be profitable. When petroleum prices declined toward yearend when the global recession resulted in reduced oil consumption, the potential profitability of the projects declined. Declining availability of credit also reduced the investments available for these projects (Park, 2008c). Alberta had announced revisions to its royalty policy in 2007 to raise royalties to 56% or 66% from 47%, but declining interest in oil sands development forced a reevaluation of the policy. The new plan offered a transitional royalty plan that would gradually increase from 2009 through 2013, with the previously announced royalties taking effect in 2014. A combination of the declining price of oil and revised royalty proposals, prompted many corporations to slash their exploration plans for Alberta (Park, 2008b).

The form of the primary product at the oil sands operation influences the quantity of sulfur produced at the oil sands operations or determine whether the sulfur is recovered at refineries at other locations. When the operators process the bitumen from the oil sands into synthetic crude oil, the sulfur is be recovered at the upgrading site. If bitumen is transported (usually by pipeline) to oil refineries specially upgraded to process this product, then the sulfur is recovered at the oil refinery, sometimes in other countries, often in the United States (Stone, 2007, 2008).

China.—China was the world's leading producer of pyrites, with 50% of sulfur in all forms coming from that source. The country was also the leading sulfur importer, with 8 Mt in 2008 (International Fertilizer Industry Association, 2010). Imports represented 90% of elemental sulfur consumption in China, with the Middle East as the leading source of the imports, followed by Canada. Phosphate fertilizer production consumed about three-quarters of the sulfuric acid produced in China. China became a net exporter of phosphate fertilizers, after having been the major destination for U.S. fertilizer exports previously.

During 2008, export tariffs were imposed to keep Chinese phosphates available for farmers in China, but those actions were part of the reason for the collapse of the phosphate and sulfur markets. Without access to the export market, Chinese phosphate producers were no longer able to afford high-priced sulfur, reducing sulfur demand in China (Sulphur, 2008b). When China curtailed much industrial activity prior to the Olympic Games that were held in Beijing in August, the country essentially withdrew from the sulfur market. Early in 2008, imports in China averaged nearly 900,000 metric tons per month, but declined substantially in August and through yearend (North America Sulphur Review, 2008g). In addition, China had amassed large sulfur stockpiles, so demand was met by drawing down stocks (Sulphur, 2008b).

In China, 70% of electricity is generated at coal-fired powerplants that emit significantly more sulfur dioxide proportionally than powerplants in Western countries. Only about 14% of the Chinese powerplants have desulfurization apparatus, and of these, not all are fully operational. Industry experts estimated that China emitted 25 Mt of sulfur dioxide from powerplants in 2008, with expectations for this to increase as electricity requirements and capacity increased. Sulfur recovery from implementing clean coal technology in China could result in the recovery of at least some of this sulfur, but no timeframe for these accomplishments was proposed (Sulphur, 2008e).

Kazakhstan.—Kazakhstan's TengizChevroil's sulfur stockpiles reached more than 9 Mt in 2008. The company produced about 1.6 million metric tons per year (Mt/yr) but exported only about 1 Mt, requiring the rest to be stockpiled. The large stockpile became a political issue in 2006, and the company was fined $600 million for violating local environmental regulations regarding the quantity of sulfur stocks allowed to be stored outside. TengizChevroil was developing plans for indoor storage of their sulfur stocks that were expected to continue to expand along with oil production at this and other operations (Sulphur, 2008d).

Although expansion plans at the Tengiz included reinjection of acid gases that would reduce the amount of elemental sulfur recovered, industry insiders forecasted that sulfur production in Kazakhstan could reach 5 Mt/yr by 2020 (Sulphur, 2008d). This figure included development of the Kashagan oil and gas field, which was expected to be completed in 2012. Reinjection of acid gases was planned for this project, capping annual sulfur production at about 1.4 Mt (Sulphur, 2008b).

Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, annually averaging about 8.7 Mt, but significant increases were expected in upcoming years as expansions, upgrades, and new facilities at existing refineries were completed. The expansions were enabling refiners to increase throughput of crude oil and to process higher sulfur crude oils; additional sulfur production will be a byproduct of refinery upgrades. Projects that had been announced before or during 2008 had the potential to add sulfur recovery capacity of more than 2.5 Mt/yr by 2013, if they were all completed on the proposed schedule (North America Sulphur Review, 2008h). In general, production from natural gas operations was expected to remain at about the same level as or decrease slightly from that of 2008 as more natural gas deposits became depleted and small-scale reinjection projects were implemented. Depletion of gas fields in the United States was likely to result in steady declines from natural gas operations over time (D'Aquin, 2005).

Worldwide recovered sulfur output was expected to increase significantly. In 2009 and 2010, production of sulfur was expected to nearly satisfy demand, but severe sulfur surpluses were expected beginning in 2011, accelerating 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. The global economic downturn, however, could slow the completion of some of the projects that were likely to contribute to the expansion of elemental sulfur supplies.

Additional production increases were expected to come from Russia's increase in sulfur recovery from natural gas and Asia's improved sulfur recovery at oil refineries and development of sour gas deposits. Refineries in developing countries were expected to improve environmental protection measures and, in the future, eventually approach the environmental standards of plants in Japan, North America, and Western Europe. Higher sulfur recovery likely will result from a number of factors, including higher refining rates, higher sulfur content in crude oil, lower allowable sulfur content in finished fuels, and reduced sulfur emissions mandated by regulations.

World consumption of natural gas is expected to maintain strong growth, and sulfur recovery from that sector likely 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 and surpluses, 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).

Domestic byproduct sulfuric acid production may fluctuate somewhat as the copper industry reacts to market conditions and varying prices by adjusting output at operating smelters. If one of the idled smelters reopened in response to high copper demand and prices, production could increase significantly, but if decreased demand for copper prompted another copper smelter to close, production would decline sharply.

Worldwide, the outlook for byproduct acid is more positive. 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 50 Mt in 2008. Worldwide, sulfur emissions at nonferrous smelters 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 likely will be from smelters in China, with additional quantities from Chile and Peru, although production from all regions was expected to increase (Sulphur, 2005).

Frasch sulfur and pyrites production, however, has little chance of significant long-term increases. Even record-high sulfur prices did not result in significantly increased production in 2008. Because of the continued increase in elemental sulfur recovery for environmental reasons rather than markets, 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 is likely to continue a steady decline. The decreases likely will be pronounced when large operations are closed outright for economic reasons, as was the case in 2000 and 2001.

For the long term, sulfur and sulfuric acid likely will continue to be important in agricultural and industrial applications. Because sulfuric acid consumption for phosphate fertilizer production was expected to increase at a lower rate than some other uses, phosphate fertilizer may become less dominant, but remain the leading end use. Ore leaching likely will be the largest area of sulfur consumption growth.

From year to year, however, the use of sulfur directly or in compounds as fertilizer likely will continue to be dependent on agricultural economies and vary according to economic conditions. If widespread use of plant nutrient sulfur is adopted, then sulfur consumption in that application could increase 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, 2006).

Industrial sulfur consumption has some prospects for growth, but not enough to consume all projected surplus production. Solvent extraction-electrowinning copper projects that consume large quantities of sulfur are under development in the United States in Arizona and Utah as well as in Chile, Congo (Kinshasa), Mexico, and Zambia. The total sulfuric acid requirement for these operations could approach 2 Mt/yr of sulfuric acid (Pearson, 2007).

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 high, as they were in 2007 and 2008, 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)

	2004	2005	2006	2007	2008
United States:					
Quantity:					
Production:					
Recovered[2]	9,380	8,790	8,390	8,280	8,690
Other	739	711	674	817 r	753
Total[e]	10,100	9,500	9,060 r	9,100 r	9,450
Shipments:					
Recovered[2]	9,410	8,770	8,290	8,310	8,670
Other	739	711	674	817 r	753
Total	10,100	9,480	8,960	9,130 r	9,430
Exports:					
Elemental[3]	949	684	635	922	952
Sulfuric acid	67	110	79	110	86
Imports:					
Elemental[e]	2,850	2,820	2,950	2,930	3,000
Sulfuric acid	784	877	793	851	1,690
Consumption, all forms[4]	12,800	12,400	12,000	11,900	13,100
Stocks, December 31, producer, recovered	185	160	221	187	211
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Recovered[e, 2]	306,000	270,000	272,000	303,000	2,130,000 e
Other	61,100	80,200	64,700	45,200 r	110,000
Total	367,000	350,000 r	337,000	349,000	2,240,000
Exports, elemental[5]	63,300	55,200	43,800	84,800	272,000
Imports, elemental	76,800	70,500	70,400	79,400	753,000
Price, elemental, f.o.b. mine or plant[e] dollars per metric ton	32.62	30.88	32.85	32.49 r	262.32
World, production, all forms (including pyrites)	66,400 r	67,200 r	67,000 r	67,500 r	68,800

[e]Estimated. [r]Revised.

[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)

State	2007 Production	2007 Shipments Quantity	2007 Shipments Value[e]	2008 Production	2008 Shipments Quantity	2008 Shipments Value[e]
Alabama	262	262	11,800	288	284	94,900
California	945	909	41,700	1,140	1,110	306,000
Illinois	511	512	11,300	458	456	51,700
Louisiana	1,550	1,550	54,600	1,600	1,610	444,000
Michigan and Minnesota	37	35	858	60	60	15,400
New Mexico	29	29	107	33	33	7,920
Ohio	102	102	3,040	139	138	44,100
Texas	2,670	2,680	107,000	2,790	2,780	830,000
Washington	130	130	3,490	136	139	30,800
Wyoming	782	793	20,700	745	733	63,200
Other[2]	1,270	1,320	48,600	1,310	1,330	237,000
Total	8,280	8,310	303,000	8,690	8,670	2,130,000

[e]Estimated.

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

[2]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)

District and source	2007 Production	2007 Shipments	2008 Production	2008 Shipments
PAD 1:				
Petroleum and coke	269	272	243	239
Natural gas	14	13	13	13
Total	283	285	257	252
PAD 2:				
Petroleum and coke	944 r	948 r	954	955
Natural gas	40 r	40 r	33	33
Total	984 r	988 r	987	988
PAD 3:[2]				
Petroleum and coke	4,620	4,650	4,780	4,790
Natural gas	509 r	516 r	549	552
Total	5,130 r	5,170 r	5,330	5,350
PAD 4 and 5:				
Petroleum and coke	1,170 r	1,150	1,400	1,380
Natural gas	716 r	720 r	721	709
Total	1,890 r	1,870 r	2,120	2,090
Grand total	8,280	8,310	8,690	8,670
Of which:				
Petroleum and coke	7,000	7,030 r	7,380	7,370
Natural gas	1,280	1,290	1,320	1,310

[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]

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2007	2008
Copper[2]	720	655
Zinc, lead, and molybdenum[3]	97 r	98
Total:		
Quantity	817 r	753
Value	45,200 r	110,000

[r]Revised.

[1]May include acid produced from imported raw materials. Data are rounded to no more than three significant digits, may not add to totals shown.

[2]Excludes acid made from pyrites concentrates.

[3]Excludes acid made from native sulfur.

TABLE 5

CONSUMPTION OF SULFUR IN THE UNITED STATES[1]

(Thousand metric tons)

	2007	2008
Elemental sulfur:		
Shipments[2]	8,310	8,690
Exports	922	952
Imports[e]	2,930	3,000
Total	10,300	10,700
Byproduct sulfuric acid:		
Shipments[2]	817 r	753
Exports[3]	110	86
Imports[3]	851	1,690
Total	1,560 r	2,360
Grand total	11,900	12,900

[e]Estimated. [r]Revised

[1]Crude sulfur or sulfur content. Data are rounded to no more than three significant digits; may not add to totals shown. Consumption is calculated as shipments minus exports imports.

[2]Includes the U.S. Virgin Islands. May include sulfuric acid other than byproduct.

[3]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)

		Elemental sulfur[2]		Sulfuric acid (sulfur equivalent)		Total	
SIC[3]	End use	2007	2008	2007	2008	2007	2008
102	Copper ores	--	--	434	456	434	456
1094	Uranium and vanadium ores	--	--	3	3	3	3
10	Other ores	--	--	57	121	57	121
26, 261	Pulpmills and paper products	W	W	245	187	245	187
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals, other chemical products[4]	W	W	245	293	245	293
281	Other inorganic chemicals	26	49	52	38	78	87
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	117	69	117	69
2823	Cellulosic fibers including rayon	--	--	156	31	156	31
284	Soaps and detergents	W	W	3	3	3	3
286	Industrial organic chemicals	--	--	47	177	47	177
2873	Nitrogenous fertilizers	--	--	21	58	21	58
2874	Phosphatic fertilizers	--	--	6,280	5,690	6,280	5,690
2879	Pesticides	--	--	8	15	8	15
287	Other agricultural chemicals	2,020	2,050	16	28	2,040	2,080
2892	Explosives	--	--	8	10	8	10
2899	Water-treating compounds	--	--	71	48	71	48
28	Other chemical products	--	--	61	34	61	34
29, 291	Petroleum refining and other petroleum and coal products	2,970	2,990	264	244	3,230	3,230
331	Steel pickling	--	--	14	6	14	6
333	Nonferrous metals	--	--	1	1	1	1
33	Other primary metals	--	--	43	5	43	5
3691	Storage batteries (acid)	--	--	21	24	21	24
	Exported sulfuric acid	--	--	15	7	15	7
	Total identified	5,010	5,090	8,180	7,540	13,200	12,700
	Unidentified	603	684	144	132	761	816
	Grand total	5,610	5,770	8,330	7,680	14,000	13,500

W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- 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]

(Thousand metric tons and thousand dollars)

Country	2007 Quantity	2007 Value	2008 Quantity	2008 Value
Argentina	53	3,130	44	16,100
Brazil	305	23,100	184	68,800
Canada	53	6,530	102	51,100
China	311	31,300	358	51,100
Mexico	66	6,880	102	43,000
Morocco	42	1,200	27	1,660
Other	92 r	12,700 r	135	39,800
Total	922	84,800	952	272,000

rRevised.

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

Country	2007 Quantity (metric tons)	2007 Value (thousands)	2008 Quantity (metric tons)	2008 Value (thousands)
Australia	1,170	$134	8	$11
Canada	170,000	13,400	160,000	11,900
Chile	14,400	655	10,700	2,840
China	994	188	1,740	369
Dominican Republic	2,990	597	4,580	539
Germany	15,100	1,780	16	43
Hong Kong	1,120	270	710	178
Ireland	1,790	1,260	1,430	1,330
Jamaica	2,680	443	5,930	1,710
Japan	14,300	1,710	48	83
Korea, Republic of	1,890	281	461	79
Mexico	8,410	1,800	14,400	3,820
Netherlands Antilles	8,100	461	5,780	1,750
Nigeria	884	101	1,300	152
Saudi Arabia	1,420	249	72	12
Singapore	15,200	1,780	53	68
Sri Lanka	--	--	1,150	132
Taiwan	31,700	4,800	113	179
Trinidad and Tobago	9,040	587	14,600	3,620
Venezuela	30,400	2,040	33,900	11,100
Other	4,400	1,680	4,820	2,720
Total	336,000	34,300	262,000	42,700

-- Zero.

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

Source: U.S. Census Bureau.

TABLE 9

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

(Thousand metric tons and thousand dollars)

	2007		2008	
Country	Quantity	Value[2]	Quantity	Value[2]
Canada	2,090 e	43,200	2,180 e	415,000
Mexico	424	16,100	365	140,000
Venezuela	406 e	17,200	360 e	134,000
Other	10	2,900	98	64,600
Total	2,930 e	79,400	3,000 e	753,000

[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 and PentaSul North American 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]

	2007		2008	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Bulgaria	--	--	26,800	$7,260
Canada	2,310,000	$101,000	2,350,000	233,000
China	775	595 r	109,000	30,100
Egypt	--	--	26,800	7,950
India	--	--	385,000 e	60,500
Japan	3,570	497	65,900	14,600
Korea, Republic of	29,200	1,190	12,100	1,200
Mexico	241,000	6,760	297,000	55,700
Peru	--	--	55,800	15,400
Poland	--	--	26,700	4,360
Sweden	--	--	25,000	6,110
Other	15,300 r	1,420 r	98,400	20,600
Total	2,600,000 r	112,000 r	3,480,000	457,000

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

[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]	2004	2005	2006	2007	2008
Australia, byproduct:[e]					
Metallurgy	870	880	880	890	880
Petroleum	60	60	58	60	58
Total	930	940	938	950	938
Canada, byproduct:					
Metallurgy	1,105	1,060	1,176	1,167 [r]	1,139 [p]
Natural gas, petroleum, oil sands	7,996	7,915	7,906	7,622 [r]	8,139 [p]
Total	9,101	8,974	9,082	8,789 [r]	9,278 [p]
Chile, byproduct, metallurgy	1,507 [r]	1,635 [r]	1,641 [r]	1,569 [r]	1,573
China:[e]					
Elemental	820	900	950	960	960
Pyrites	3,730	4,010	3,810	4,200	4,300
Byproduct, metallurgy	2,600	2,800	3,000	3,300	3,350
Total	7,150	7,710	7,760	8,460	8,610
Finland:[e]					
Pyrites	336	270	250	250	250
Byproduct:					
Metallurgy	301	300	300	300	300
Petroleum	65	70	65	65	65
Total	702	640	615	615	615
France, byproduct:					
Natural gas and petroleum	707	622	616	606	605 [e]
Unspecified[e]	698 [4]	750	750	700	700
Total	1,405	1,372	1,366	1,306	1,310 [e]
Germany, byproduct:					
Metallurgy[e]	591 [4]	600 [4]	600	600	600
Natural gas and petroleum	1,503 [r]	1,585 [r]	1,686 [r]	1,637 [r]	1,709
Total	2,094 [r]	2,185 [r]	2,286 [r]	2,237 [r]	2,309
India:[e]					
Pyrites	32	32	32	32	32
Byproduct:					
Metallurgy	539	580	600	590	600
Natural gas and petroleum	501	520	540	530	540
Total	1,070	1,130	1,170	1,150	1,170
Iran, byproduct:[e]					
Metallurgy	60	60	65	70	70
Natural gas and petroleum	1,400	1,400	1,400	1,500	1,500
Total	1,460	1,460	1,470	1,570	1,570
Italy, byproduct:[e]					
Metallurgy	113	92	90	90	90
Petroleum	575	650	650	650	650
Total	688	742	740	740	740
Japan, byproduct:					
Metallurgy	1,263	1,284	1,343	1,250 [e]	1,300
Petroleum	1,895	1,972	1,950	1,966 [r]	1,970
Total	3,158	3,256	3,293	3,216 [r]	3,270
Kazakhstan, byproduct:[e]					
Metallurgy	325	325	300	300	300
Natural gas and petroleum	1,650	1,700	1,700	1,661 [r, 4]	1,733 [4]
Total	1,980	2,030	2,000	1,960 [r]	2,030

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]	2004	2005	2006	2007	2008
Korea, Republic of, byproduct:[e]					
Metallurgy	796	850 [r]	900 [r]	900 [r]	900
Petroleum	879	850 [r]	950 [r]	950 [r]	950
Total	1,680	1,700 [r]	1,850 [r]	1,850 [r]	1,850
Kuwait, byproduct, natural gas and petroleum[e]	682	700	650	700	700
Mexico, byproduct:					
Metallurgy[e]	703	750 [r]	650 [r]	550 [r]	700
Natural gas and petroleum	1,122	1,017	1,074	1,026 [r]	1,041
Total	1,825	1,767 [r]	1,724 [r]	1,576 [r]	1,741
Netherlands, byproduct:[e]					
Metallurgy	137	135	130	130	130
Petroleum	410	400	400	400	400
Total	547	535	530	530	530
Poland:[e, 5]					
Frasch	821	802	800 [4]	834 [4]	762 [4]
Byproduct:					
Metallurgy	292 [r]	292 [r]	307 [r]	304 [r]	305
Natural gas	23	21	20	28	21
Petroleum	158 [r]	164 [r]	182 [r]	188 [r]	190
Total	1,290 [r]	1,280 [r]	1,310 [r]	1,350 [r]	1,280
Russia:[e, 6]					
Native	50	50	50	50	50
Pyrites	300	300	200	200	200
Byproduct:					
Metallurgy	570	600	700	800	820
Natural gas	6,000	6,000	6,000	6,000	6,100
Total	6,920	6,950	6,950	7,050	7,170
Saudi Arabia, byproduct, all sources	2,249	2,717	2,907 [r]	3,089 [r]	3,163
South Africa:					
Pyrites, S content, from gold mines	165	133	68	71	61 [p]
Byproduct:					
Metallurgy, copper, platinum, zinc plants	180	220	231	236 [r]	210 [e]
Petroleum	288	422	343	335 [r]	298 [e]
Total	633	776	643	642 [r]	569 [e]
Spain, byproduct:[e]					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	500	500	500	500	500
Petroleum	150	115	100	100	100
Total	651	616	601	601	601
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,930	1,950	1,950	1,950	1,950
United States, byproduct:					
Metallurgy	739	711	674	817 [r]	753
Natural gas	1,990	1,850	1,430 [r]	1,280	1,320
Petroleum	7,390	6,940	6,960	7,000	7,380
Total	10,100	9,500	9,060 [r]	9,100 [r]	9,450
Uzbekistan, byproduct:[e]					
Metallurgy	170	170	170	170	170
Natural gas and petroleum	350	350	350	350	350
Total	520	520	520	520	520

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]	2004	2005	2006	2007	2008
Venezuela, byproduct, natural gas and petroleum[e]	800	800	800	800	800
Other[e]	5,280 r	5,310 r	5,140 r	5,180 r	5,100
Of which:					
Frasch	20	20 r	21 r	22 r	22
Native[7]	270	236	201	200	199
Pyrites	167	161	155 r	150 r	153
Unspecified	1,330	1,380	1,150 r	1,140 r	1,100
Byproduct:					
Metallurgy	1,310 r	1,290 r	1,340 r	1,370 r	1,370
Natural gas	361 r	361 r	361 r	361 r	361
Natural gas and petroleum, undifferentiated	496 r	521 r	529 r	512 r	485
Petroleum	1,330	1,340 r	1,380 r	1,420 r	1,410
Grand total	66,400 r	67,200 r	67,000 r	67,500 r	68,800
Of which:					
Frasch	841	822	821 r	856 r	784
Native[8]	1,140	1,190	1,200	1,210	1,210
Pyrites	4,730	4,910	4,520	4,900	5,000
Unspecified	4,270	4,850	4,810 r	4,930 r	4,960
Byproduct:					
Coal, lignite, gasification[e]	1	1	1	1	1
Metallurgy	14,700 r	15,100 r	15,600 r	15,900 r	16,100
Natural gas	8,370 r	8,230 r	7,810 r	7,670 r	7,800
Natural gas, petroleum, oil sands, undifferentiated	19,100	19,100	19,200	18,900 r	19,600
Petroleum	13,200 r	13,000 r	13,000	13,100	13,500

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

[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 14, 2009.

[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, oil 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 oil 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]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.

[5]Reported figure.

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

[7]Excludes "China, elemental" and "Russia, native."

[8]Includes "China, elemental" and "Russia, native."