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SULFUR [ADVANCE RELEASE]

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SULFUR

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The sulfur industry experienced an unusual year in 2007. It began with the expectations of additional sulfur surpluses as had been the case for several years prior to 2007. A series of events, however, resulted in a shortage of material available in the global market. Beginning early in 2007 and extending through midyear, several petroleum refineries in the United States experienced outages that resulted in lower than expected sulfur recovery at those sites.

More important to the international market, however, was a rail strike in western Canada that, coupled with poor weather conditions in the same region, severely curtailed the amount of sulfur available for export from the world's leading sulfur exporter. Limited export material and booming demand for sulfur for fertilizer manufacturing around the world, with especially strong demand in China and India, set the stage for a significant run-up in prices. Although prices began 2007 on a downward trend, global prices began to increase during the first quarter, and domestic prices followed suit by midyear. Prices continued to climb toward record-high levels through yearend, with no indications of a turnaround.

In 2007, total domestic production of sulfur was virtually the same as it was in 2006. Elemental sulfur recovered at petroleum refineries was slightly higher than it was in 2006, but sulfur recovered from natural gas operations decreased by 11%, continuing the general downward trend from that source that began in 1998.

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; 36.1 million metric tons (Mt), which is equivalent to about 11.8 Mt of elemental sulfur, was produced in 2007, slightly more than that of 2006 (U.S. Census Bureau, 2008).

In 2007, domestic production of sulfur in all forms was virtually unchanged; shipments of sulfur in all forms increased slightly from those of 2006. Production of elemental sulfur decreased slightly, but shipments of elemental sulfur were about the same as they were in 2006, resulting in a 15% decrease in producers' stocks. Byproduct sulfuric acid production and shipments were 19% higher. Apparent consumption decreased slightly, imports increased slightly, and exports increased by 45% in response to strong global demand and high international prices. Unit values averaged about 10% higher for the year in the United States, resulting in the value of elemental sulfur shipments increasing by about 11%; the total value of byproduct sulfuric acid decreased by 30%, even though shipments increased (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 sulfur, naturally occurring elemental sulfur, was slightly higher. In the few countries where pyrites remain an important raw material for sulfuric acid production, strong demand and high sulfur prices resulted in a 9% increase in sulfur production from pyrites.

For the past 5 years, between 82% and 84% of the world's sulfur production came from recovered sources, as both elemental sulfur and byproduct sulfuric acid. 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 thought to be slightly higher than it was in 2006; typically, about 50% is used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur increased about 6% from the levels reported in 2006. Worldwide inventories of elemental sulfur declined.

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 the 101 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2007, production was slightly lower than that of 2006, and shipments were about the same as those of 2006. The value of shipments was 11% higher than that in 2006 owing to a slight increase in quantity and a 10% increase in the average domestic unit value of elemental sulfur. Although U.S. petroleum refineries operated at generally high rates, accidents, technical problems, and weather emergencies at a few of refineries limited the amount of sulfur that could be recovered.

Recovery from natural gas operations decreased again. One large gas-processing plant experienced technical problems, a few gas plants were closed as the deposits were depleted, and at least one began reinjecting its acid gases.

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 2007, 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 were, in descending order of production, Valero Energy Corp., Exxon Mobil Corp., ConocoPhillips Co., Chevron Corp., and Shell Oil Co. (including its joint ventures with Petróleos Mexicanos, and Saudi Refining, Inc. and subsidiary operations). The 45 plants owned by these companies accounted for 60% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

Many refiners across the country were partnering with Canadian oil sands producers and 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 also can be much lower in price. Many such projects, representing more than $5.3 billion in investments, were underway or planned and expected to be completed by 2012 (North American Sulphur Review, 2006a). Examples of this type of project included BP America Inc.'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, 2006b). Marathon Oil Corp. planned to upgrade its Detroit, MI, refinery to increase its capacity to process heavy oils, such as the type produced at the Canadian oil sands operations. An additional 100,000 t/yr is expected from this refinery by 2010. Marathon increased its stake in oil sands developments by acquiring a 20% share in the Athabasca Oil Sands Partnership operated by Shell (North American Sulphur Review, 2007c).

BP America and Husky Energy Inc. formed a partnership to develop the Sunrise oil sands field in Alberta and expand BP America's Toledo, OH, refinery to process the bitumen produced at Sunrise. Each company will hold a 50% share of both operations. The refinery's capacity to process heavy crude oils will increase to 170,000 barrels per day (bbl/d) from its current 60,000 bbl/d by 2015. As with any projects of this type, sulfur recovery capacity will increase also (Izundu, 2007). In 2006, Suncor Energy, Inc. completed upgrades at its Commerce City, CO, refinery to enable the plant to process high-sulfur crude oils from its oil sands operations in Fort McMurray, Alberta, Canada (Sulphur, 2006a). Other refineries in the United States most likely to receive Canadian oil sands products for further processing are complex refineries in northern States, although refineries on the Gulf Coast could also be candidates (Nakamura, 2007a).

In 2007, 6 of the 20 largest oil refineries in the world were in the United States. In descending order of throughput 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 America's Texas City, TX, refinery; Citgo's Lake Charles, LA, refinery; and BP America's Whiting, IN, refinery (Nakamura, 2007b). 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 are refined at the specific refineries. Major refineries that process low-sulfur crude oils may have relatively low sulfur production. According to a survey conducted by Oil & Gas Journal, 39% of sulfur recovery capacity at oil refineries worldwide was in the United States, although U.S. crude capacity was only 20% of the world total (Koottungal, 2007).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 8.8% of the total domestic production of sulfur in all forms and totaled the equivalent of 803,000 t of elemental sulfur. The portion of total sulfur product represented by byproduct sulfuric acid and the quantity produced increased by 19% mostly as the result of increased copper 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 mines and accounted for 90% of the 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 nearly the same as that of 2006 (table 5). Of the sulfur consumed, 68% was obtained from domestic sources—

elemental sulfur (62%) and byproduct acid (5.8%)—compared with 69% in 2006, 70% in 2005, and 72% in 2004 and 2003. The remaining 32% was supplied by imports of recovered elemental sulfur (25%) and sulfuric acid (7.2%). 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 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 4.8%, and total reported sulfur consumption decreased by 3.3%. These decreases in consumption can be attributed in large part to the decrease in sulfuric acid consumed in industrial 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 increased slightly to 8.34 Mt compared with 8.27 Mt in 2006. Reported consumption of sulfur in the production of phosphatic fertilizers and other agricultural chemicals was slightly higher than that of 2006. Based on export data reported by the U.S. Census Bureau (2008), the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased by 16% to 4.0 Mt. More than 50% of domestic fertilizer production typically is exported, as was the case in 2007, but exports declined as a result of strong domestic demand for corn that was planted for food and biofuels applications and more competition in the global fertilizer market.

The second ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported a 4.4% 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, increased by 33% because production of electrowon copper increased in response to strong demand and higher prices for copper.

The U.S. Census Bureau (2008) also reported that 2.3 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 decreased to 187,000 t, 15% less than those of 2006 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 6-day supply compared with a 7-day supply in 2006, a 5-day supply in 2005 and 2004 each, and a 6-day supply in 2003. Final stocks in 2007 represented 3.3% 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

Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was estimated to be $36.29 per metric ton, which was about 10% higher than that of 2006. The increased value reported by producers correlated with prices recorded in trade publications. Although the reported increases were lower than might have been expected, these were the average values for the entire year, taking the lower prices from early in the year into account.

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at $58.50 to $61.50 per ton. In February, prices decreased to $54.00 to $57.00 per ton. In August, prices rose to $82.50 to $85.50 per ton and rose again in November to $110.50 to $113.50 per ton. They remained at that level through the remainder of the year, although industry sources indicated that increases might continue well into 2008.

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 2007, U.S. west coast prices varied from less than $0 per ton to $110 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 that can be shipped overseas. The majority of west coast sulfur was shipped overseas. Global sulfur prices generally were higher than domestic prices in 2007.

Foreign Trade

Strong international demand and high prices resulted in exports of elemental sulfur from the United States, including the U.S. Virgin Islands, increasing by 45% in quantity and by 94% in value compared with those of 2005. The average unit value of export material was $91.98 per ton, an increase of 33% from $68.95 per ton in 2006 (table 7). The leading destination for this material was China, followed by Brazil, Mexico, and Canada. Export facilities on the gulf coast that began shipping in 2006 have become an important source for exported sulfur. Exports from the west coast were 422,000 t, or 46% of total U.S. exports. Exports from the gulf coast were 291,000 t, or 32% 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 2006, but higher prices for imported material resulted in the value being 13% higher than it was in 2006. Imports from Canada, mostly by rail, were estimated to be virtually the same in quantity as those of 2006, waterborne shipments from Mexico were 11% lower than those of 2006, and waterborne imports from Venezuela were estimated to have increased by 13%. Canada was the source of an estimated 71% of elemental sulfur imports, and Mexico and Venezuela, 14% each (table 9).

In addition to elemental sulfur, the United States had significant trade in sulfuric acid. Sulfuric acid exports were 36% higher than those of 2006 (table 8). Acid imports were nearly eight times greater than exports (tables 8, 10). Canada and Mexico were the sources of 98% of acid imported into the United States, 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 Asia and Europe. The tonnage of sulfuric acid imports was about 7% more than that of 2006, and the value of imported sulfuric acid increased by 31%.

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 2007 (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 86% 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, in descending order by quantity, by Canada, Russia, Saudi Arabia, the United Arab Emirates, Kazakhstan, Iran, the United States, and Japan; these countries exported more than 1 Mt of elemental sulfur each and accounted for almost 77% of total sulfur trade. Major sulfur importers were, in descending order, China, Morocco, the United States, Brazil, India, and Tunisia, all with imports of more than 1 Mt.

After 15 years of sulfur surpluses, significantly increased demand in China and India resulted in a supply deficit in 2007, creating record-high prices by yearend 2007. Price trends indicated further increases for about the next year, but high prices were not expected to last long. Although actual production was closely balanced with consumption, the remote location of some producers kept that material from the market, inducing the drawdown of more accessible stockpiles (Sulphur, 2007a).

Prices in most of the world were thought to have averaged significantly higher throughout 2007 than in the previous year. Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was about 4% higher than that of 2006. Recovered elemental sulfur production and byproduct sulfuric acid production increased slightly compared with those of 2006. Available supplies of sulfur in all forms were less than consumption for the first time in several years in 2007, although the actual quantity of shortfall was unclear. Worldwide sulfur inventories, much of which was stockpiled in Canada and Kazakhstan, were sufficient to meet increased demand. Stocks in Canada and Kazakhstan declined owing to the strong international demand for sulfur. Globally, production of sulfur from pyrites increased by about 9%, 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.

Canada.—Ranked second in the world in sulfur production, Canada was the leading sulfur and sulfuric acid exporter. In 2007, sulfur production in Canada was slightly lower than it was the previous year. About two-thirds of Canadian sulfur is recovered at natural gas operations in Alberta, with some recovered from gas in British Columbia and from oil refineries in other parts of the country. Recovery from natural gas has declined for several years, leading to recent decreases in sulfur production in Canada, and that trend was expected to continue.

The amount of sulfur recovered at gas operations in Alberta and British Columbia was estimated to be 5.6 Mt in 2007, about 6.5% less than that in 2006. Significant increases in production from oil sands operations and minor increases at refineries were expected, and will contribute to Canada remaining a leader in global sulfur production. Byproduct acid production was expected to remain relatively stable (Stone, 2007, 2008; North American Sulphur Review, 2008).

An estimated 1.1 Mt of sulfur was remelted from stockpiles in 2007. Stocks decreased to about 11.8 Mt in Alberta in 2007, nearly 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 (North American Sulphur Review, 2007c; Stone, 2008).

Canada has exported between 8 and 9 Mt of sulfur every year since 2003. Most of Canada's sulfur exports passed through the port of Vancouver on their way to China (60%), and Australia, Brazil, and South Africa in 2007. Also, large quantities of sulfur are transported to the United States by rail also. Poor weather conditions in western Canada contributed to the low availability of export material in Vancouver early in the year. Coupled with shipping problems related to a rail strike, Canadian sulfur producers were forced to stockpile sulfur in Alberta that was impossible to ship. The shipping difficulties in Canada resulted in supply shortfalls in other parts of the world, which, in turn, spurred increased prices. After the rail strike ended and weather conditions improved in the spring, a large backlog of material had been amassed, and supplies remained tight while the accumulated material was shipped (Green Markets, 2007a, b; Sulphur, 2007a).

Oil sands development is the fastest growing industry in Canada. Expansions at oil sands operations could 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, 2007a). The Athabasca oil sands were 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 form of the primary product at the oil sands operation will influence the quantity of sulfur produced at the oil sands operations or determine whether the sulfur will be recovered at refineries at other locations. When the operators process the bitumen from the oil sands into synthetic crude oil, the sulfur will 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 will be recovered at the oil refinery, sometimes in other countries, often in the United States (Stone, 2007, 2008).

The government of Alberta increased the royalties on oil sands projects, resulting in total taxes at these operations of 56% to 66%, depending on the price of oil, up from 47%. Because oil prices were on an upward trend, the increased royalties were not expected to deter further development. If petroleum prices decline, however, the additional royalties could put a damper on oil sands development (North American Sulphur Review, 2007b).

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 9.6 Mt in 2007, much of which was used to produce sulfuric acid consumed in the production of phosphate fertilizers.

In 2007, elemental sulfur recovery capacity in China was about 2 million metric tons per year (Mt/yr) at chemical plants, natural-gas-processing facilities, and oil refineries, although production was thought to be less than one-half that. Most of the production is from oil refineries. Recently discovered natural gas deposits in Sichuan Province contain 10.4% to 17.1% hydrogen sulfide, which must be removed before the natural gas can be used. When these deposits are developed, sulfur production at the associated gas processing plants could be significant.

By 2010, additional sulfur recovery in China is expected from three sources. About 200,000 t/yr may come from existing natural gas plants, perhaps up to 4 Mt/yr from newly developed sour gas fields, and possibly as much as 3 Mt/yr from refineries. This would represent a total of 7.2 Mt/yr of elemental sulfur from new sources. In the same timeframe, consumption was expected to increase to 11 Mt/yr, maintaining the necessity of sulfur imports. At that point, China may surpass the United States as the leading consumer of sulfur in the world (Zhao, 2007).

Kazakhstan.—Large quantities of sulfur were recovered in Kazakhstan at Tengizchevroil's (TCO) Tengiz oil field. The Government of Kazakhstan fined TCO $609 million for amassing excessive stocks of sulfur at Tengiz between 2003 and 2006. The Kazakh authorities were concerned that the stockpile was damaging the environment. TCO [a joint venture of Chevron (50%), ExxonMobil (25%), KazMunayGas (20%), and LukArco (5%)] was appealing the fine while it increased sulfur sales to reduce the stocks (Watkins, 2007).

The associated natural gas at Tengiz contains 14% hydrogen sulfide. In 2007, TCO was operating at a sulfur production rate of about 1.6 Mt/yr with plans to increase production to 2.4 Mt/yr by 2009. The majority of production was sent to TCO's forming plant. Prior to 2007, TCO had amassed a stockpile of about 8.9 Mt, but during 2007, shipments outpaced production, and the size of the stockpile decreased. The company was in the process of installing remelt facilities so the material removed from stocks could be granulated and sold as premium product. TCO expected sales of 3 Mt/yr, but with plans for reinjection of acid gases, that would result in lower sulfur production, and thus lower sulfur sales eventually. Acid gas reinjection should have the additional advantage of enhancing oil and gas recovery from the reservoir (Tengizchevroil Environmental Communications Group, 2007).

The U.S. Department of Energy and the U.S. Department of State have sponsored research in Kazakhstan to develop new or expanded uses for byproduct sulfur in Kazakhstan and to provide projects to keep Soviet-era weapons scientists engaged. These programs have focused on increasing and improving construction applications for sulfur, including sulfur polymer concrete, synthetic aggregate for road construction, sulfur-extended asphalt paving, stabilization of mercury, and encapsulation of radioactive waste. The researchers make the case that sulfur polymer concrete is environmentally friendly because it replaces portland cement concrete in various applications, thus limiting greenhouse gas emissions from cement plants (Kalb and others, 2007).

Venezuela.—The Government of Venezuela nationalized its oil industry early in 2007, with PdVSA taking over the operation of oil fields, including those in the Orinoco Belt, the source of vast quantities of extremely heavy oil, and the source of much of Venezuela's sulfur production. Foreign oil companies had invested an estimated $17 billion in these projects that had grown in value to more than $30 billion. The Government of Venezuela invited the foreign oil companies to stay on as minority partners. The compensation offered was thought to be much lower than the investments that were made in the projects (North American Sulphur Review, 2007a). Venezuela also planned to collect taxes retroactively based on the assertion that the arrangement by which foreign companies were taxed was illegal, and these companies owed $3 billion in back taxes (Sulphur, 2007b).

Venezuela had the capability to produce about 600,000 t/yr of sulfur, mostly from the Orinoco Belt. Much of this sulfur was exported to other countries in South America, Brazil in particular. Future increases in sulfur production will be tied to expansions at the heavy oil projects, but the political situation puts new developments in question, at least temporarily (Sulphur, 2007b).

Outlook

Although domestic elemental sulfur production decreased for the third consecutive year, the industry was expected to resume the trend 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 after hurricanes damaged refineries in 2005, but significant 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 crude oils; additional sulfur production will be a byproduct of refining upgrades. Production from natural gas operations in 2008 was expected remain about the same level as or decrease slightly from that of 2007 as more natural gas deposits became depleted and small-scale reinjection projects were implemented. Depletion of gas fields in the United States is likely to result in a further decrease of 100,000 t/yr from natural gas operations over time (D'Aquin, 2005).

Worldwide recovered sulfur output is expected to increase significantly. For the next 1 or 2 years, sulfur supply was expected to nearly equal demand. Severe sulfur surpluses, however, were expected beginning in 2010, 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 Venezuela's heavy-oil processors.

Additional production 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 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, 2006b).

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 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).

Byproduct acid production may fluctuate somewhat as the copper industry reacts to market conditions and varying prices by adjusting output at currently operating smelters. Additionally, if one of the idled smelters reopened in response to high copper demand and prices, production could increase significantly, but if decreased demand prompts another copper smelter to close, production could 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 2007. 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, 2005).

Frasch sulfur and pyrites production, however, has little chance of significant long-term increases, although higher sulfur prices have resulted in temporary increases in production and consumption. Because of the continued increase in 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. When sulfur prices are extremely high as they were in 2007, discretionary sulfur production may increase in response to the price situation, either to avoid the high sulfur prices or to take advantage of unusual profit opportunities.

Sulfur and sulfuric acid 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. World sulfur consumption in fertilizer was forecast to increase by 2.6% per year for the next 10 years; industrial consumption is expected to grow by 2.2% per year.

Increased use of sulfur directly or in compounds as fertilizer 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, 2006b).

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 of sulfuric acid per year (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, 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)

		2003	2004	2005	2006	2007
United States:						
Quantity:						
Production:						
Recovered[2]		8,910	9,380	8,790	8,390	8,280
Other		683	739	711	674	803
Total		9,600	10,100	9,500	9,060	9,090
Shipments:						
Recovered[2]		8,970	9,410	8,770	8,290	8,310
Other		725	739	711	674	803
Total		9,690	10,100	9,480	8,960	9,120
Exports:						
Elemental[3]		840	949	684	635	922
Sulfuric acid		67	67	110	79	110
Imports:						
Elemental[e]		2,870	2,850	2,820	2,950	2,930
Sulfuric acid		297	784	877	793	851
Consumption, all forms[4]		11,900	12,800	12,400	12,000	11,900
Stocks, December 31, producer, recovered		206	185	160	221	187
Value:						
Shipments, free on board (f.o.b.) mine or plant:						
Recovered[e, 2]		256,000	306,000	270,000	272,000	303,000
Other		34,000	61,100	80,200	64,700	45,300
Total		290,000	367,000	351,000	337,000	349,000
Exports, elemental[5]		54,400	63,300	55,200	43,800	84,800
Imports, elemental		70,600	76,800	70,500	70,400	79,400
Price, elemental, f.o.b. mine or plant[e]	dollars per metric ton	28.70	32.62	30.88	32.85	36.29
World, production, all forms (including pyrites)		64,100 r	66,200 r	67,000 r	66,900 r	68,400

[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)

	2006			2007		
		Shipments			Shipments	
State	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	245	245	9,580	262	262	11,800
California	1,140	1,090	20,700	945	909	41,700
Illinois	510	511	15,700	511	512	11,300
Louisiana	1,270	1,270	48,400	1,550	1,550	54,600
Michigan and Minnesota	36	37	1,060	37	35	858
New Mexico	30	30	113	29	29	107
Ohio	129	129	4,840	102	102	3,040
Texas	2,700	2,690	103,000	2,670	2,680	107,000
Washington	125	124	3,600	130	130	3,490
Wyoming	880	870	21,900	782	793	20,700
Other[2]	1,330 r	1,300	43,200	1,270	1,320	48,600
Total	8,390 r	8,290	272,000	8,280	8,310	303,000

[e]Esitmated. [r]Revised.

[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)

	2006		2007	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	229	227	269	272
Natural gas	42	42	14	13
Total	271	269	283	285
PAD 2:				
Petroleum and coke	1,030	1,030	936	940
Natural gas	40	40	35	34
Total	1,070	1,070	971	974
PAD 3:[2]				
Petroleum and coke	4,330	4,290	4,620	4,650
Natural gas	483	484	469	475
Total	4,820	4,780	5,090	5,130
PAD 4 and 5:				
Petroleum and coke	1,360 r	1,310	1,180	1,150
Natural gas	871 r	859	764	772
Total	2,240 r	2,170	1,940	1,930
Grand total	8,390 r	8,290	8,280	8,310
Of which:				
Petroleum and coke	6,960	6,870	7,000	7,020
Natural gas	1,440 r	1,430	1,280	1,290

[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	2006	2007
Copper[3]	576	720
Zinc, lead, and molybdenum[4]	98	83
Total:		
Quantity	674	803
Value	64,700	45,300

[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)

	2006	2007
Elemental sulfur:		
Shipments[4]	8,290	8,310
Exports	635	922
Imports[e]	2,950	2,930
Total	10,600	10,300
Byproduct sulfuric acid:		
Shipments[4]	674	803
Exports[5]	79	110
Imports[5]	793	851
Total	1,390	1,540
Grand total	12,000	11,900

[e]Estimated.

[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. May include sulfuric acid other than by product.

[5]May include sulfuric acid other than by product.

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[3]		Sulfuric acid (sulfur equivalent)		Total	
SIC[2]	End use	2006	2007	2006	2007	2006	2007
102	Copper ores	--	--	327	434	327	434
1094	Uranium and vanadium ores	--	--	2	3	2	3
10	Other ores	--	--	47	57	47	57
26, 261	Pulpmills and paper products	W	W	246	245	246	245
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals, other chemical products[4]	W	W	426	245	426	245
281	Other inorganic chemicals	89	26	42	52	131	78
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	250	117	250	117
2823	Cellulosic fibers including rayon	--	--	156	156	156	156
284	Soaps and detergents	W	W	3	3	3	3
286	Industrial organic chemicals	--	--	88	47	88	47
2873	Nitrogenous fertilizers	--	--	25	21	25	21
2874	Phosphatic fertilizers	--	--	6,220	6,280	6,220	6,280
2879	Pesticides	--	--	2	8	2	8
287	Other agricultural chemicals	2,010	2,020	12	16	2,020	2,040
2892	Explosives	--	--	8	8	8	8
2899	Water-treating compounds	--	--	64	71	64	71
28	Other chemical products	--	--	334	61	334	61
29, 291	Petroleum refining and other petroleum and coal products	3,120	2,970	262	264	3,380	3,230
30	Rubber and miscellaneous plastic products	W	W	3	4	3	4
331	Steel pickling	--	--	13	14	13	14
333	Nonferrous metals	--	--	1	1	1	1
33	Other primary metals	--	--	38	43	38	43
3691	Storage batteries (acid)	--	--	23	21	23	21
	Exported sulfuric acid	--	--	22	15	22	15
	Total identified	5,220	5,010	8,610	8,190	13,800	13,200
	Unidentified	990	603	132	144	606 r	761
	Grand total	6,210	5,610	8,750	8,330	14,400 r	14,000

[r]Revised. 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]Standard industrial classification.

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

[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)

	2006		2007	
Country	Quantity	Value	Quantity	Value
Argentina	9	468	53	3,130
Brazil	184	10,800	305	23,100
Canada	97	7,570	53	6,530
China	95	8,240	311	31,300
Mexico	40	2,010	66	6,880
Morocco	121	4,620	42	1,200
Senegal	57	2,700	17	770
Other	32	7,350	75	11,900
Total	635	43,800	922	84,800

[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]

	2006		2007	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	7,270	$297	--	--
Aruba	1,630	399	--	--
Australia	5	4	1,170	$134
Brazil	11,800	510	439	75
Canada	94,900	8,350	170,000	13,400
Chile	--	--	14,400	655
Dominican Republic	3,510	510	2,990	597
Germany	864	207	15,100	1,780
Hong Kong	115	116	1,120	270
Ireland	3,500	1,170	1,790	1,260
Jamaica	3,130	239	2,680	443
Japan	54	83	14,300	1,710
Korea, Republic of	109	436	1,890	281
Mexico	6,550	1,320	8,410	1,800
Netherlands Antilles	4,480	257	8,100	461
Peru	14,100	1,630	--	--
Saudi Arabia	1,440	306	1,420	249
Singapore	4,440	548	15,200	1,780
Taiwan	318	229	31,700	4,800
Trinidad and Tobago	22,100	1,000	9,040	587
Venezuela	62,700	2,800	30,400	2,040
Other	5,310	1,780 r	5,840	1,890
Total	248,000	22,200 r	336,000	34,300

[r]Revised. -- 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)

	2006		2007	
Country	Quantity	Value[2]	Quantity	Value[2]
Canada	2,100 [e]	33,000	2,090 [e]	43,200
Mexico	476	20,100	424	16,100
Venezuela	359 [e]	15,100	406 [e]	17,200
Other	19	2,170	10	2,900
Total	2,950 [e]	70,400	2,930 [e]	79,400

[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 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]

	2006		2007	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	1,980,000	$79,200	2,310,000	$101,000
Chile	15,800	215	--	--
Germany	58,000	1,400	3,570	497
Indonesia	--	--	15,000	1,310
Japan	38,600	768	3,570	497
Korea, Republic of	--	--	29,200	1,190
Mexico	198,000	4,810	241,000	6,760
Netherlands	9,520	392	--	--
Poland	13,600	229	--	--
Spain	29,200	756	--	--
Sweden	39,900	1,070	--	--
Switzerland	43,100	278	--	--
Other	1,250 [r]	1,010 [r]	1,100	6,890
Total	2,430,000	90,100	2,610,000	118,000

[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]	2003	2004	2005	2006	2007
Australia, byproduct:[e]					
Metallurgy	863	870	880	880	890
Petroleum	60	60	60	58 [r]	60
Total	923	930	940	938 [r]	950
Canada, byproduct:					
Metallurgy	992	1,105 [r]	1,060 [r]	1,176 [r]	1,185 [p]
Natural gas, petroleum, tar sands	8,036	7,996 [r]	7,915 [r]	7,906 [r]	7,782 [p]
Total	9,028	9,101 [r]	8,974 [r]	9,082 [r]	8,967 [p]
Chile, byproduct, metallurgy	1,462 [r]	1,508 [r]	1,659 [r]	1,664 [r]	1,573 [p]
China:[e]					
Elemental	700	820	900	950 [r]	960
Pyrites	3,400	3,730	4,010	3,810 [r]	4,200
Byproduct, metallurgy	2,400	2,600	2,800	3,000	3,300
Total	6,500	7,150	7,710	7,760 [r]	8,460
Finland:[e]					
Pyrites	341	336	270	250	250
Byproduct:					
Metallurgy	305	301	300	300	300
Petroleum	60	65	70	65	65
Total	706	702	640	615	615
France, byproduct:					
Natural gas and petroleum	710	707 [r]	622 [r]	616 [r]	606
Unspecified	710 [r]	698 [r]	750 [r, e]	750 [r, e]	700 [e]
Total	1,420 [r]	1,405 [r]	1,372 [r]	1,366 [r]	1,306
Germany, byproduct:					
Metallurgy	701	591	600 [e]	600 [e]	600 [e]
Natural gas and petroleum	1,661	1,503	1,585	1,686	1,700 [e]
Total	2,362	2,094	2,185	2,286	2,300 [e]
India:[e]					
Pyrites	32	32	32	32	32
Byproduct:					
Metallurgy	539	539	580	600	590
Natural gas and petroleum	451	501	520	540	530
Total	1,022	1,072	1,132	1,172	1,152
Iran, byproduct:[e]					
Metallurgy	50	60	60	65	70
Natural gas and petroleum	1,310	1,400	1,400	1,400	1,500
Total	1,360	1,460	1,460	1,465	1,570
Italy, byproduct:[e]					
Metallurgy	127	113	92 [r]	90 [r]	90
Petroleum	565	575	650 [r]	650 [r]	650
Total	692	688	742 [r]	740 [r]	740
Japan, byproduct:					
Metallurgy	1,281	1,263	1,284	1,343 [r]	1,250 [e]
Petroleum	1,951	1,895	1,972	1,950 [r]	1,950 [e]
Total	3,232	3,158	3,256	3,293 [r]	3,200 [e]
Kazakhstan, byproduct:[e]					
Metallurgy	325	325	325	300	300
Natural gas and petroleum	1,600	1,650	1,700	1,700	2,300
	1,925	1,975	2,025	2,000	2,600

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]	2003	2004	2005	2006	2007
Korea, Republic of, byproduct:[e]					
Metallurgy	797	796	800	800	800
Petroleum	757	879	885	890	890
Total	1,554	1,675	1,685	1,690	1,690
Kuwait, byproduct, natural gas and petroleum[e]	714	682	700	650	700
Mexico, byproduct:					
Metallurgy[e]	539	703	700	700	700
Natural gas and petroleum	1,052	1,122	1,017	1,074	1,070 [e]
Total	1,591	1,825	1,717	1,774	1,770 [e]
Netherlands, byproduct:[e]					
Metallurgy	131	137	135	130	130
Petroleum	408	410	400	400	400
Total	539	547	535	530	530
Poland:[e, 4]					
Frasch	762	821	802	800 [5]	834 [5]
Byproduct:					
Metallurgy	175 [r]	175 [r]	175 [r]	205 [r]	215
Petroleum	294 [r]	275 [r]	275 [r]	275 [r]	275
Total	1,231 [r]	1,271 [r]	1,252 [r]	1,280 [r]	1,324
Russia:[e, 6]					
Native	50	50	50	50	50
Pyrites	350	300	300	200 [r]	200
Byproduct:					
Metallurgy	520	570	600	700 [r]	800
Natural gas	5,800	6,000	6,000	6,000	6,000
Total	6,720	6,920	6,950	6,950 [r]	7,050
Saudi Arabia, byproduct, all sources[e]	2,180	2,249 [5]	2,717 [5]	2,900 [r]	3,100
South Africa:					
Pyrites, S content, from gold mines	176	165	133	68	71 [p]
Byproduct:					
Metallurgy, copper, platinum, zinc plants	174	180	220	231 [r]	230 [e]
Petroleum	264	288	422	343 [r]	340 [e]
Total	614	633	776	643 [r]	641 [e]
Spain, byproduct:[e]					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	500	500	500	500	500
Petroleum	150	150	115 [r]	100 [r, p]	100 [p]
Total	651	651	616 [r]	601 [r]	601
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,900	1,930	1,950	1,950	1,950
United States, byproduct:					
Metallurgy	683	739	711	674	803
Natural gas	1,940	1,990	1,850 [r]	1,440 [r]	1,280
Petroleum	6,970	7,390	6,940	6,960 [r]	7,000
Total	9,600	10,100	9,500 [r]	9,070 [r]	9,090
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]	560	800	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]	2003	2004	2005	2006	2007
Other[e]	5,100 r	5,160 r	5,180 r	5,170 r	5,230
Of which:					
Frasch	19	20	20	20	20
Native[7]	297	270	236	201 r	200
Pyrites	170	167	161	152	152
Unspecified	1,310 r	1,330 r	1,380 r	1,350 r	1,340
Byproduct:					
Metallurgy	1,250 r	1,190 r	1,190 r	1,210 r	1,240
Natural gas	301	361	361	361	361
Natural gas and petroleum, undifferentiated	469 r	491 r	516 r	524 r	520
Petroleum	1,280	1,330	1,320	1,350	1,400
Grand total	64,100 r	66,200 r	67,000 r	66,900 r	68,400
Of which:					
Frasch	781	841	822	820	854
Native[8]	1,050	1,140	1,190	1,200 r	1,210
Pyrites	4,470	4,730	4,910	4,510 r	4,900
Unspecified	4,210 r	4,270 r	4,850 r	5,000 r	5,140
Byproduct:					
Coal, lignite, gasification[e]	1	1	1	1	1
Metallurgy	14,000 r	14,400 r	14,800 r	15,300 r	15,700
Natural gas	8,040	8,350	8,210 r	7,800 r	7,640
Natural gas, petroleum, tar sands, undifferentiated	18,800	19,100	19,100 r	19,200 r	19,800
Petroleum	12,800 r	13,300 r	13,100 r	13,000	13,100

[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 17, 2008.

[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]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.”