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SULFUR

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SULFUR

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In 2009, the sulfur price began the year at its lowest level in U.S. history. The U.S. market was suffering from a downturn in demand for goods in all sectors. In the fertilizer industry, the phosphate sector, which includes seven U.S. producers, was operating at levels of about 25% of capacity in an attempt to continue production with essentially no demand. In May, prices began to move upwards. In the last quarter of the year, market conditions improved slightly as production and consumption of phosphate rock and fertilizers increased.

The United States was second in world sulfur production, with China's sulfur production surpassing that of the United States for the first time. 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 world.

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; 29.1 million metric tons (Mt), which is equivalent to about 9.5 Mt of elemental sulfur, was produced in 2009, 8% less than in 2008 (U.S. Census Bureau, 2010).

In 2009, domestic production of sulfur in all forms was 4% lower than 2008; shipments of sulfur in all forms decreased by about 5%. Elemental sulfur recovered at petroleum refineries was 4% lower than it was in 2008, and sulfur recovered from natural gas operations decreased by 7%. Producers' stocks increased by 10%, representing about 3% of shipments. Byproduct sulfuric acid production and shipments declined slightly. Apparent consumption of sulfur in all forms decreased by 27%. Imports of elemental sulfur and sulfuric acid combined decreased by 55%. Exports increased by 45%, primarily as a result of a large increase in elemental sulfur exports. The average unit value in 2009 was the lowest recorded value dating as far back as 1900 for the United States, resulting in the value of elemental sulfur shipments decreasing by almost 99% compared with the 2008 value of shipments. The total value of byproduct sulfuric acid shipments more than doubled, even though the quantity of shipments decreased by about 5% (table 1).

Worldwide, compliance with environmental regulations has contributed to sulfur recovery; however, in 2009 there was a slight decrease 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 23%. In the few countries where pyrites remain an important raw material for sulfuric acid production, strong demand 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 have been, 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 slightly lower than it was in 2008; typically, about 50% was used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur decreased slightly from the levels reported in 2008. Worldwide inventories of elemental sulfur were higher.

Legislation and Government Programs

In December, the U.S. Environmental Protection Agency (EPA) finalized more stringent standards for control of emissions from new marine compression-ignition engines at or above 30 liters per cylinder. EPA's strategy included Clean Air Act standards, as well as implementation of the international standards for marine engines and their fuels contained in Annex VI to the International Convention on the Prevention of Pollution from Ships (MARPOL). Also included in these standards was the designation of U.S. coasts as an Emission Control Area (ECA) through an amendment to MARPOL Annex VI.

The final rule provided flexibility on complying with fuel sulfur requirements. Vessels could use other methods to achieve sulfur dioxide emission reductions equivalent to those obtained by the use of lower sulfur fuel. In addition, a fuel availability relief provision was added for use only by vessels with diesel engines operating on the Great Lakes and the Saint Lawrence Seaway. This provision allowed operators to buy the lowest sulfur marine residual fuel available that met the near-term 1.0% (10,000 parts per million) fuel sulfur standard. Also, existing steamships operating on the Great Lakes and Saint Lawrence Seaway were exempt from the ECA-level fuel sulfur standards in MARPOL Annex VI (U.S. Environmental Protection Agency, 2009).

On July 17, 2009, the International Maritime Organization (IMO) approved in principal a proposal from the United States and Canada to amend MARPOL Annex VI to designate an ECA off the United States and Canadian coasts. The ECA would ensure that ships affecting the U.S. air quality meet stringent nitrogen oxides and fuel sulfur requirements while operating within the designated area, up to 370 kilometers (km) (200 nautical miles) off U.S. coastlines and Hawaii (U.S. Environmental Protection Agency, 2009). California advanced separate regulations and issued a Marine Notice that only distillate fuels can be used within 44.4 km (24 nautical miles) of its shore beginning in July (Oil & Gas Journal, 2009b).

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 103 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2009, production was 4% lower than that of 2008, and shipments were about 5% lower. After the tremendous price increase for elemental sulfur during 2008 and the subsequent collapse, the value of shipments was 99% less than of that of 2008. Owing to decreased demand for petroleum products, several U.S. petroleum refineries operated at reduced rates. In addition, accidents, technical problems, and weather emergencies at a few refineries limited the amount of sulfur that could be recovered. For 2009, on average, U.S. petroleum refineries operated at 82.8% of capacity and by yearend, at only 80% (North American Sulphur Review, 2010d).

During the 2009 hurricane season, only one tropical storm and one Category 2 hurricane formed within the Gulf of Mexico. The tropical storm passed well east of the oil-and-sulfur-producing region. The hurricane passed directly over the region, but had weakened to a tropical storm by the time it passed over the producing region. Offshore energy producers reported only minor impacts from the Category 2 hurricane, with estimated shut-in production of 2.5 million barrels of crude oil and 322 million cubic meters of natural gas (U.S. Energy Information Administration, 2010b).

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 34 companies at 101 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 2009; 15 produced between 50,000 and 100,000 t; 35 produced between 10,000 and 50,000 t; and 23 plants produced less than 10,000 t. By source, 86% 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 were, all with more than 500,000 t of sulfur production, in descending order of production, Valero Energy Corp., Exxon Mobil Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), Chevron Corp., Shell Oil Co. (including its joint ventures with Petróleos Mexicanos and Saudi Refining, Inc.), Citgo Petroleum Corp., and BP p.l.c. The 55 plants owned by these companies accounted for 74% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

Valero announced that it would permanently close its 210,000 barrels per day Delaware City, DE, refinery. Sulfur production at the site was 80,000 to 90,000 t/yr, some of which was consumed onsite (North America Sulfur Review, 2009a).

In 2009, 6 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; Citgo Petroleum Corp.'s Lake Charles, LA, refinery; and Marathon's Garyville, LA, refinery (Oil & Gas Journal, 2009a). 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 (2009c, p. 3), the United States operated 20% of world refining capacity, but had almost 40% of sulfur recovery capacity at refineries.

According to data from the National Petrochemical & Refiners Association (2010, p. 1), U.S. refining capacity rose by more than 5% from 2003 through 2009 and by more than 8% from 1999 through 2009, without building any new refineries and with a few small operations closing. In 2009, U.S. refinery capacity was 18 million barrels per day. 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 2009, new or expansion projects were underway or in the planning stages at 18 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 new projects were expected to be completed in 2009, but most were expected to be completed between 2010 and 2012 (Sulphur, 2010).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 8% of total domestic production of sulfur in all forms and totaled the equivalent of 749,000 t of elemental sulfur. The portion of total sulfur product represented by byproduct sulfuric acid and the total quantity produced decreased slightly (table 4). Three acid plants operated in conjunction with copper smelters, and three 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 90% 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 27% lower than that of 2008 (table 5). Of the sulfur consumed, 83% was obtained from domestic sources as elemental sulfur (76%) and byproduct acid (7%) compared with 69% in 2008, 68% in 2007, 69% in 2006, and 70% in 2005. The remaining 17% was supplied by imports of recovered elemental sulfur (14%) and sulfuric acid (3%). 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 67% 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 87% 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) increased slightly, and total reported sulfur consumption decreased by 14%. These reported decreases in consumption can be attributed to the 15% decrease in agricultural chemicals and 18% decrease in petroleum refining. 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 15% to 6.65 Mt compared with 7.84 Mt in 2008 because of decreased production of other agricultural chemicals. Based on export data reported by the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased by about 4% to 4.5 Mt. More than 50% of domestic fertilizer production typically is exported, as was the case in 2009.

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 decreased by 18% from that of 2008. Demand for sulfuric acid in copper ore leaching, which was the third ranked end use, decreased by 20%.

The U.S. Census Bureau (2010) also reported that 2.2 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 232,000 t, 10% more than those of 2008 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 9-day supply, compared with a 6-day supply in 2008 and 2007 each, a 7-day supply in 2006, and a 5-day supply in 2005. Final stocks in 2009 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, the low 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 $1.73 per metric ton, which was 99% lower than that of 2008. The decreased value reported by producers correlated with the trends in prices recorded in trade publications. In 2009, the lowest average value of shipments was reported, which dates as far back as 1900 for the United States.

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at $136 per ton. In February, prices decreased to $0 per ton. In May, prices increased slightly to $5 per ton and again increased in August to $9 per ton. Prices remained at that level until November, when they increased to $27 per ton. Although the Tampa contract price remained at that level through the end of 2009, price increases were expected in 2010.

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 2009, U.S. West Coast prices varied from less than $0 per ton to $15 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. World sulfur prices generally were higher than domestic prices in 2009.

The Abu Dhabi National Oil Co.'s (ADNOC) monthly contract price became the bellwether of sulfur pricing during 2008. Even though prices varied by location, provider, and type, the ADNOC price became a recognized indicator of sulfur price trends. In 2009, the ADNOC contract 2009 price averaged nearly $44 per ton, with the lowest price of $33 per ton in August and the highest price of $57 per ton in December (North America Sulphur Review, 2009b; 2010b).

Foreign Trade

Strong international demand during much of the year resulted in exports from the United States, including the U.S. Virgin Islands, increasing by about 50% in quantity and decreasing by 70% in value compared with those of 2008. The average unit value of export material was $58 per ton, a decrease of 79% from $285 in 2008 (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 620,000 t, or 44% of total U.S. exports. Exports from the Gulf Coast were 750,000 t, or 53% of the U.S. total.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by about

275,000 t. 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 43% less in quantity than those of 2008, and lower prices for imported material resulted in the value being about 92% less than that of 2008. Imports from Canada, mostly by rail, were estimated to be 34% lower than those of 2008, waterborne shipments from Mexico were 66% lower, and waterborne imports from Venezuela were estimated to have decreased by 61%. Canada was the source of an estimated 84% of elemental sulfur imports, and Mexico and Venezuela at 7% and 8%, respectively (table 9).

In addition to elemental sulfur, the United States had significant trade in sulfuric acid. Sulfuric acid exports were 3% lower than those of 2008 (table 8). Acid imports were about 5 times greater than exports (tables 8, 10). Canada and Mexico were the sources of 73% 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 76% less than that of 2008, and the value of imported sulfuric acid decreased by almost 69%.

World Review

The world 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 2009 (table 11).

Poland was the only country that produced more than 250,000 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 92% of the total sulfur produced worldwide. In 2009, about 29 Mt of elemental sulfur was traded globally. The leading exporters were, in decreasing order of tonnage, Canada, Kazakhstan, Saudi Arabia, Russia, the United States, the United Arab Emirates, Japan, and Iran, all with more than 1 Mt of exports. The leading importer was China, by far, followed by, in decreasing order of tonnage, Morocco, the United States, Tunisia, Brazil, and India. All of the top importing countries had large phosphate fertilizer industries (International Fertilizer Industry Association, 2011).

Supply growth stalled in 2009 as world production was virtually static. Prices generally were stable in the first half of 2009 and showed an increase toward the end of 2009. International prices for 2009 averaged higher than those in the United States. Although actual sulfur production was lower than in 2008, consumption and supply were balanced. Chinese imports were in excess of their average annual consumption.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was about 23% lower than that of 2008. Recovered elemental sulfur production decreased by 4% and byproduct sulfuric acid production decreased slightly compared with those of 2008. For most of 2009, owing to the falling demand in the fertilizer and industrial sectors new sulfur production was limited. However, the lower world production, recovering sulfur consumption, and strong imports from China, created tight market conditions by yearend and continued into 2010. Globally, production of sulfur from pyrites decreased slightly. With lower sulfur prices, pyrites become a less attractive alternative to elemental sulfur for sulfuric acid production. The environmental remediation costs of mining pyrites are more onerous when the price for sulfur is low, as additional costs are incurred when using this less environmentally friendly raw material.

Canada.—Ranked third in the world in sulfur production, Canada was the leading sulfur and sulfuric acid exporter. In 2009, sulfur production in Canada was 8% lower than it was in 2008. 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 offsets that, and this trend was expected to continue. Sulfur production from natural gas processing declined by 13% in 2009, while sulfur production from the oil sands operations continued its upward trend. Production from oil sands was about 15% higher in 2009 than in 2008 (North America Sulphur Review, 2010a).

Canada's sulfur production was expected to remain stable over the medium term and may increase over the long term as a result of expanded oil sands production. Sulfur production from natural gas was expected to decline as natural gas reserves decrease. Significant increases in production from oil sands operations and minor increases at refineries were expected. Canada was likely to remain a leader in world sulfur production. Byproduct acid production was expected to remain relatively stable (Stone, 2010).

Xstrata Plc (Switzerland) announced that it would permanently cease operation at its copper and zinc plants at Kidd Creek, Ontario, in May 2010. The closure would remove a significant volume of merchant sulfuric acid from the North American market. The estimated sulfuric acid production at Kidd Creek was 500,000 t/yr (North America Sulphur Review, 2009a).

A report from Alberta's Energy Resources Conservation Board (ERCB) published in 2010 showed that sulfur emissions in 2009 from Alberta's natural gas processing plants declined by 59% from levels in 2000 and 12% from those of 2008. 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 recovered declined during the same period because of lower gas processing volumes (Energy Resources Conservation Board, 2010, p. 5).

An estimated 800,000 t of sulfur was added to Canada's stockpiles in 2009. Stocks increased to about 12.3 Mt in Alberta in 2009, 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, 2010).

Oil sands 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 world 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, 2008).

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).

In 2009, more elemental sulfur was recovered from Canadian oil sands than in 2008, when the world economic downturn had a negative impact on Canadian oil sands projects. However, oil sands operations require tremendous capital to develop, and only high oil prices allow them to be profitable (Stone, 2010).

The form of the primary product at the oil sands operation influences the quantity of sulfur produced at the oil sands operations or determines 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 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.—For the first time, China was the leading producer of sulfur in all forms. It also was the world's leading producer of pyrites, with about 50% of its sulfur in all forms coming from that source. The country was the leading sulfur importer, with 12.5 Mt in 2009 (International Fertilizer Industry Association, 2011). Imports represented 90% of elemental sulfur consumption in China, with the Middle East as the leading source of the imports, followed by Canada. Fertilizer production consumed about three-quarters of the sulfuric acid produced in China.

During the second half of 2008, export tariffs were imposed to keep Chinese phosphates available for farmers in China, but those actions caused shutdowns among fertilizer producers. In July 2009, export tariffs were reduced by 10% in response to the request for a reduction. Fertilizer production was China's primary application for sulfuric acid, and long-term prospects for Chinese fertilizer demand were expected to remain strong. In 2009, strong global imports were driven by heavy purchases of sulfur by China. However, the short-term demand for sulphuric acid was negatively affected by the slump in the fertilizer markets (Sulphur, 2009b).

Without access to the export market, Chinese phosphate producers were only supplying the domestic market rather than increasing revenue by exporting phosphate fertilizer (Sulphur, 2009b). In 2009, China imports averaged about 816,000 metric tons per month of elemental sulfur, with the largest quantities of imports entering the country during the first 6 months of the year (North America Sulphur Review, 2010c). China had sulfur stockpiles of more than 2 months' worth of demand (Sulphur, 2009b).

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, 2008).

The Zinjin Copper Industry Co. (a subsidiary of the Zihn Mining Group Co.) announced plans to build a 200,000-t/yr copper smelting plant in the Fuijan Province. The smelter was expected to produce 700,000 t/yr of sulphuric acid (Sulphur, 2009a).

Kazakhstan.—Kazakstan's largest phosphate producer, Kazphosphate LLC, signed a memorandum of understanding with state company United Chemical Co. (UCC) to build a 650,000-t/yr sulphuric acid complex as part of a major phosphate joint venture at the Karatau phosphate field. The sulphuric acid plant was to be built in Taraz as part of the second phase that was scheduled to begin in 2011. The cost of the two phases of the project was estimated to be nearly $250 million (Sulphur, 2009d).

Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.6 million metric tons per year (Mt/yr), 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 2009 had the potential to add sulfur recovery capacity of more than 2.8 Mt/yr by 2013, if all were completed on proposed schedules (Sulphur, 2010). In general, production from natural gas operations was expected to remain at about the same level as or increase from that of 2009 as more natural gas is recovered from shale formations, horizontal drilling, and hydraulic fracturing. More efficient, cost-effective drilling techniques, primarily in shale formations, will be important for U.S. natural gas production (U.S. Energy Information Administration, 2010a).

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.

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 was 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 was 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 about 70 Mt in 2014 from about 60 Mt in 2009. 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. In 2009, Frasch sulfur production decreased by 50%. 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 is expected to 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. Expansions of phosphate fertilizer production were expected to be constructed in 10 countries, one-half of them in China, with additional facilities planned in Africa, Asia, and Latin America (Heffer and Prud'homme, 2010).

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 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. Concrete made with sulfur is more resistant to acid and saltwater; the manufacturing process lowers CO_2 emissions and does not require water to manufacture (Sulphur, 2009c). However, when sulfur prices are high, 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)

	2005	2006	2007	2008	2009
United States:					
Quantity:					
Production:					
Recovered[2]	8,790	8,390	8,280	8,550 r	8,190
Other	711	674	817	753	749
Total[e]	9,500	9,060	9,100	9,300 r	8,940
Shipments:					
Recovered[2]	8,770	8,290	8,310	8,530 r	8,110
Other	711	674	817	753	749
Total	9,480	8,960	9,130	9,280 r	8,860
Exports:					
Elemental[3]	684	635	922	953 r	1,430
Sulfuric acid	110	81 r	110	86	83
Imports:					
Elemental[e]	2,820	2,950	2,930	3,000	1,700
Sulfuric acid	877	802 r	857 r	1,690	413
Consumption, all forms[4]	12,400	12,000	11,900	12,900 r	9,460
Stocks, December 31, producer, recovered	160	221	187	211	232
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Recovered[e, 2]	270,000	272,000	303,000	2,250,000 r	14,000 e
Other	80,200	64,700	45,200	110,000	234,000
Total	350,000	337,000	349,000	2,360,000 r	248,000
Exports, elemental[5]	55,200	437,000 r	84,800	272,000	82,200
Imports, elemental	70,500	70,400	79,400	753,000	54,100
Price, elemental, f.o.b. mine or plant[e] dollars per metric ton	30.88	32.85	36.49 r	264.04 r	1.73
World, production, all forms (including pyrites)	68,200 r	67,500 r	68,200 r	68,700 r	67,500

[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)

	2008			2009		
		Shipments			Shipments	
State	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	285 r	281 r	94,900	268	264	-4,490
California	1,140	1,110	327,000 r	1,010	1,000	4,280
Illinois	458	456	51,700	457	457	-1,160
Louisiana	1,460 r	1,470 r	399,000 r	1,330	1,370	10,300
Michigan and Minnesota	36 r	36 r	9,410 r	35	35	-679
New Mexico	33	33	7,920	25	25	388
Ohio	139	138	44,100	133	133	460
Texas	2,790	2,780	830,000	2,900	2,860	4,450
Washington	136	139	30,800	125	126	-284
Wyoming	745	733	63,200	656	668	3,600
Other[2]	1,330 r	1,360 r	392,000 r	1,250	1,170	-2,880
Total	8,550 r	8,530 r	2,250,000 r	8,190	8,110	14,000

[e]Estimated. [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)

	2008		2009	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	243	239	168	166
Natural gas	13	13	13	13
Total	257	252	181	179
PAD 2:				
Petroleum and coke	954	955	945	932
Natural gas	33	33	28	28
Total	987	988	973	960
PAD 3:[2]				
Petroleum and coke	4,650 r	4,650 r	4,580	4,580
Natural gas	537 r	552	546	485
Total	5,180 r	5,200 r	5,120	5,060
PAD 4 and 5:				
Petroleum and coke	1,400	1,380	1,280	1,270
Natural gas	721	709	627	638
Total	2,120	2,090	1,910	1,910
Grand total	8,550 r	8,530 r	8,190	8,110
Of which:				
Petroleum and coke	7,240 r	7,220 r	6,970	6,950
Natural gas	1,300 r	1,310	1,220	1,160

[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	2008	2009
Copper[2]	655	671
Zinc, lead, and molybdenum[3]	98	79
Total:		
Quantity	753	749
Value	110,000	234,000

[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)

	2008	2009
Elemental sulfur:		
Shipments[2]	8,530 r	8,110
Exports	953 r	1,430
Imports[e]	3,000	1,700
Total	10,600 r	8,380
Byproduct sulfuric acid:		
Shipments	753	749
Exports[3]	86	83
Imports[3]	1,690	413
Total	2,360	1,080
Grand total	12,900	9,460

[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 plus imports.

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

[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)

SIC[3]	End use	Elemental sulfur[2] 2008	Elemental sulfur[2] 2009	Sulfuric acid (sulfur equivalent) 2008	Sulfuric acid (sulfur equivalent) 2009	Total 2008	Total 2009
102	Copper ores	--	--	456	363	456	363
1094	Uranium and vanadium ores	--	--	3	2	3	2
10	Other ores	--	--	121	112	121	112
26, 261	Pulpmills and paper products	W	W	187	188	187	188
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals, other chemical products[4]	W	W	293	286	293	286
281	Other inorganic chemicals	49	1	38	99	87	100
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	69	64	69	64
2823	Cellulosic fibers including rayon	--	--	31	7	31	7
284	Soaps and detergents	W	W	3	3	3	3
286	Industrial organic chemicals	--	--	177	36	177	36
2873	Nitrogenous fertilizers	--	--	58	161	58	161
2874	Phosphatic fertilizers	--	--	5,690	5,430	5,690	5,430
2879	Pesticides	--	--	15	9	15	9
287	Other agricultural chemicals	2,050	1,000	28	44	2,080	1,050
2892	Explosives	--	--	10	10	10	10
2899	Water-treating compounds	--	--	48	64	48	64
28	Other chemical products	--	--	34	250	34	250
29, 291	Petroleum refining and other petroleum and coal products	2,990	2,360	244	283	3,230	2,650
331	Steel pickling	--	--	6	8	6	8
333	Nonferrous metals	--	--	1	--	1	--
33	Other primary metals	--	--	5	5	5	5
3691	Storage batteries (acid)	--	--	24	28	24	28
	Exported sulfuric acid	--	--	7	197	7	197
	Total identified	5,090	3,370	7,540	7,650	12,600 r	11,000
	Unidentified	684	489	132	91	816	585
	Grand total	5,770	3,860	7,680	7,740	13,400 r	11,600

[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]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	2008 Quantity	2008 Value	2009 Quantity	2009 Value
Brazil	184	68,800	383	15,600
Canada	102	51,100	29	5,730
China	358	51,100	731	39,800
Mexico	102	43,000	127	8,030
Morocco	27	1,660	33	1,610
Other	180 r	55,800 r	122	11,400
Total	953	272,000	1,430	82,200

r Revised.

[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	2008 Quantity (metric tons)	2008 Value (thousands)	2009 Quantity (metric tons)	2009 Value (thousands)
Canada	160,000	$11,900	212,000	$14,300
Chile	10,700	2,840	--	--
China	1,740	369	2,750	371
Dominican Republic	4,580	539	649	149
El Salvador	10	20	469	74
Germany	16	43	494	102
Greece	662	82	505	60
Hong Kong	710	178	21	57
Ireland	1,430	1,330	1,180	1,500
Israel	604	771	2,680	2,340
Jamaica	5,930	1,710	--	--
Korea, Republic of	461	79	79	30
Mexico	14,400	3,820	3,810	1,150
Netherlands Antilles	5,780	1,750	3,040	539
Nigeria	1,300	152	1	9
Phillipines	92	128	469	313
Poland	139	335	825	94
Singapore	53	68	66	143
Sri Lanka	1,150	132	--	--
Taiwan	113	179	843	205
Thailand	44	40	463	95
Trinidad and Tobago	14,600	3,620	4,760	543
Venezuela	33,900	11,100	16,400	1,070
Other	3,400 r	1,450 r	2,230	767
Total	262,000	42,700	254,000	23,900

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)

	2008		2009	
Country	Quantity	Value[2]	Quantity	Value[2]
Canada	2,180	415,000	1,430 e	45,800
Mexico	366 r	140,000	125	2,540
Venezuela	360	134,000	140 e	2,400
Other	98	64,600	6	3,390
Total	3,000	753,000	1,700 e	54,100

[e]Estimated. [r]Revised.

[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]

	2008		2009	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Bulgaria	26,800	$7,260	29,100	$481
Canada	2,350,000	233,000	821,000	118,000
China	109,000	30,100	392	386
Egypt	26,800	7,950	--	--
Finland	23,000	3,600	39,300	4,040
India	2,070,000 r	60,500	--	--
Japan	65,900	14,600	20,000	477
Korea, Republic of	12,100	1,200	37,000	4,160
Mexico	297,000	55,700	108,000	4,750
Peru	55,800	15,400	66,700	2,300
Poland	26,700	4,360	30,200	434
Sweden	25,000	6,110	15,600	742
Other	94,800 r	28,400 r	98,200	10,300
Total	5,180,000 r	468,000 r	1,260,000	146,000

[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]	2005	2006	2007	2008	2009
Australia, byproduct:[e]					
Metallurgy	880	880	890	880	870
Petroleum	60	58	58 [r]	60 [r]	60
Total	940	938	948 [r]	940 [r]	930
Brazil:					
Frasch	20	21	22	22 [e]	22 [e]
Byproduct:					
Metallurgy	267	298	322	322	322 [p]
Petroleum	112	117	136	136	136 [p]
Total	399	436	480	480	480
Canada, byproduct:					
Metallurgy	1,058 [r]	1,176	1,167	1,148 [r]	890
Natural gas, petroleum, oil sands	7,915	7,906	7,622	7,008 [r]	6,577
Total	8,973 [r]	9,082	8,789	8,156 [r]	7,467
Chile, byproduct, metallurgy	1,635	1,641	1,569	1,573	1,627
China:[e]					
Elemental	900	950	960	960	1,000
Pyrites	4,010	3,810	4,200	4,300	4,370
Byproduct, metallurgy	2,800	3,000	3,300	3,350	4,000
Total	7,710	7,760	8,460	8,610	9,370
Finland:[e]					
Pyrites	270	250	250	250	250
Byproduct:					
Metallurgy	300	300	300	300	300
Petroleum	70	70 [r]	70 [r]	70 [r]	70
Total	640	620 [r]	620 [r]	620 [r]	620
France, byproduct, all sources[e]	616 [r]	650 [r]	650 [r]	650 [r]	650
Germany, byproduct:					
Metallurgy	2,292 [r]	2,437 [r]	2,454 [r]	2,458 [r]	2,137
Natural gas and petroleum	1,585	1,686	1,637	1,709	1,623
Total	3,877 [r]	4,123 [r]	4,091 [r]	4,167 [r]	3,760
India:[e]					
Pyrites	32	32	32	32	32
Byproduct:					
Metallurgy	580	600	590	600	590
Natural gas and petroleum	520	540	530	540	530
Total	1,130	1,170	1,150	1,170	1,150
Iran, byproduct:[e]					
Metallurgy	60	60 [r]	70	70	70
Natural gas and petroleum	1,400	1,400	1,500	1,500	1,500
Total	1,460	1,460 [r]	1,570	1,570	1,570
Italy, byproduct:[e]					
Metallurgy	92	90	90	90	90
Petroleum	650	650	650	650	650
Total	742	740	740	740	740
Japan, byproduct:					
Metallurgy	1,284	1,343	1,250	1,300 [e]	1,350 [e]
Petroleum	1,972	1,950	1,966	2,034 [r]	1,864
Total	3,256	3,293	3,216	3,334 [r]	3,214

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]	2005	2006	2007	2008	2009
Kazakhstan, byproduct:[e]					
Metallurgy	325	300	300	300	300
Natural gas and petroleum	1,700	1,700	1,661 [4]	1,733 [4]	1,700
Total	2,025	2,000	1,960	2,030	2,000
Korea, Republic of, byproduct:[e]					
Metallurgy	800 [r]	660 [r]	670 [r]	660 [r]	600
Petroleum	900 [r]	950	1,000 [r]	900 [r]	900
Total	1,700	1,610 [r]	1,670 [r]	1,560 [r]	1,500
Kuwait, byproduct, natural gas and petroleum[e]	836 [r]	742 [r]	830 [r]	830 [r]	830
Mexico, byproduct:					
Metallurgy[e]	750	650	550	700	700
Natural gas and petroleum	1,017	1,074	1,026	1,041	1,000 [e]
Total	1,767	1,724	1,576	1,741	1,700 [e]
Netherlands, byproduct:[e]					
Metallurgy	141 [r]	111 [r]	115 [r]	115 [r]	115
Petroleum	400	400	400	400	400
Total	541 [r]	511 [r]	515 [r]	515 [r]	515
Poland:[e, 5]					
Native	802	800	834	762	263
Byproduct:					
Metallurgy	292	307	304	294 [r]	260
Natural gas	21	20	23 [r]	21	21
Petroleum	164	182	188	201 [r]	180
Other	2	2	2	3	3
Total	1,280	1,310	1,350	1,280	727
Russia:[e, 6]					
Native	50	50	50	50	50
Pyrites	300	200	200	200	200
Byproduct:					
Metallurgy	600	700	800	820	820
Natural gas	6,000	6,000	6,000	6,100	6,000
Total	6,950	6,950	7,050	7,170	7,070
Saudi Arabia, byproduct, all sources	2,717	2,907	3,089	3,163	3,214
South Africa:					
Pyrites, S content, from gold mines	133	68	71	61	60
Byproduct:					
Metallurgy, copper, platinum, zinc plants	220	231	236	187 [r]	176 [e]
Petroleum	422	343	335	323 [r]	303 [e]
Total	776	643	642	571 [r]	539 [e]
Spain, byproduct:[e]					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	500	500	500	500	500
Petroleum[6]	112 [r]	117 [r]	136 [r]	136 [r]	136 [p]
Total	613 [r]	618 [r]	637 [r]	637 [r]	637
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,950	1,950	1,950	2,175 [r, 4]	2,175 [4]
United States, byproduct:					
Metallurgy	711	674	817	753	749
Natural gas	1,850	1,430	1,280	1,300 [r]	1,220
Petroleum	6,940	6,960	7,000	7,240 [r]	6,970
Total	9,500	9,060	9,100	9,300 [r]	8,940

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]	2005	2006	2007	2008	2009
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]	800	800	800	800	800
Other[e]	4,870 r	4,230 r	4,250 r	4,410 r	4,760
Of which:					
Frasch	-- r	-- r	-- r	-- r	--
Native[7]	236	201	200	206 r	207
Pyrites	161	155	150	153	130
Unspecified	1,380	1,150	1,140	1,150 r	1,190
Byproduct:					
Metallurgy	1,020 r	1,040 r	1,050 r	1,050 r	1,050
Natural gas	361	361	361	528 r	659
Natural gas and petroleum, undifferentiated	475 r	481 r	472 r	428 r	722
Petroleum	1,230 r	833 r	875 r	898 r	810
Grand total	68,200 r	67,500 r	68,200 r	68,700 r	67,500
Of which:					
Frasch	20 r	21 r	22 r	22 r	22
Native[8]	1,990 r	2,000 r	2,040 r	1,980 r	1,520
Pyrites	4,910	4,520	4,900	5,000	5,040
Unspecified	4,710	4,710	4,880	4,960	5,050
Byproduct:					
Coal, lignite, gasification[e]	1	1	1	1	1
Metallurgy	16,800 r	17,200 r	17,500 r	17,600 r	17,700
Natural gas	8,230	7,810	7,670	7,950 r	7,900
Natural gas, petroleum, oil sands, undifferentiated	18,500 r	18,600 r	18,400 r	18,100 r	17,800
Petroleum	13,000	12,600 r	12,800 r	13,100 r	12,500

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

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

[2]Table includes data available through July 28, 2010.

[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]Reported figure.

[5]Government of Poland sources report total Frasch and native mined elemental sulfur output annually, undifferentiated.

[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.”