



# 2010 Minerals Yearbook

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## SULFUR

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In 2010, the global economy began to recover from the recession of 2008–09, which resulted in an increase in consumption and prices for sulfur. Demand for sulfur was strong in the phosphate sector because the fertilizer producers needed to restock their product inventories after operating at low production levels in 2009. In addition, phosphate fertilizer producers operated at high rates to keep up with increasing demand for fertilizers. Sulfur imports were up significantly compared with those in 2009 owing to the demand for sulfur in the production of fertilizers and industrial sectors.

The United States was second in world sulfur production following China. 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; 32.5 million metric tons (Mt), which is equivalent to about 10.6 Mt of elemental sulfur, was produced in 2010, about 12% more than that in 2009 (U.S. Census Bureau, 2011).

In 2010, domestic production of sulfur in all forms was slightly higher than in 2009; shipments of sulfur in all forms increased by about 3%. Elemental sulfur recovered at petroleum refineries was slightly higher than it was in 2009, and sulfur recovered from natural gas operations decreased by 4%.

Producers' stocks decreased by 29%, representing about 2% of shipments. Byproduct sulfuric acid production and shipments increased by about 6%. Apparent consumption of sulfur in all forms increased by 19%. Imports of elemental sulfur and sulfuric acid combined increased by 72% and exports remained about the same. The average unit value in 2010 was about 40 times higher, resulting in the value of elemental sulfur shipments increasing by a factor of nearly 7 compared with the 2009 value of shipments. The total value of byproduct sulfuric acid shipments increased by about 6% (table 1).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; for 2010, global sulfur production increased slightly. Recovered elemental sulfur is produced primarily during the processing of natural gas and crude petroleum. Estimated worldwide production of native (naturally occurring elemental) sulfur increased by 23%. In the few countries where pyrites remain an important raw material for sulfuric acid production, sulfur production from pyrites was slightly lower.

Since 2005, between 82% and 83% 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 estimated to have increased from that of 2009; typically, about 50% was used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur increased from the levels reported in 2009. Worldwide inventories of elemental sulfur were tight owing to the increased demand for sulfur, although stocks at remote operations remained high.

## Legislation and Government Programs

In June, the U.S. Environmental Protection Agency (EPA) finalized the primary National Ambient Air Quality Standard (NAAQS) for sulfur dioxide (SO<sub>2</sub>). The revised standard established a new 1-hour SO<sub>2</sub> standard at a level of 75 parts per billion. EPA also revoked its 24-hour and annual primary SO<sub>2</sub> standards, which were established in 1971. The rule likely would affect coal-burning utilities and copper and other nonferrous metal smelters that would need to reduce emissions under the new standard (U.S. Environmental Protection Agency, 2010, p. 2).

In July, the Governor of New York State signed a bill into law (S.1145–C) that limits sulfur in home heating oil. The bill limits the sulfur content of No. 2 heating oil for use in residential, commercial, or industrial heating applications to no more than 15 parts per million (ppm) starting in July 2012, down from the current range of 2,000 to 10,000 ppm. This is the same standard set by the EPA for diesel fuel (New York State Governor, 2010).

## 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 102 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2010, production was slightly higher than that of 2009, and shipments were about 3% higher. Increased price and demand for sulfur resulted in the value of shipments being more than six and a half times higher than of that of 2009. Accidents, technical problems, maintenance, and weather issues at a few refineries limited the amount of sulfur that could be recovered. For 2010, on average, U.S. petroleum refineries operated at

86.4% of capacity, a 4% increase from that of 2009 (U.S. Energy Information Administration, 2011c).

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 102 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, 32 produced more than 100,000 metric tons (t) of elemental sulfur in 2009, 15 produced between 50,000 and 100,000 t, 36 produced between 10,000 and 50,000 t, and 20 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, all with more than 500,000 t of sulfur production, in descending order of production, were Exxon Mobil Corp., Valero Energy Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), Chevron Corp., BP p.l.c., and Marathon Petroleum Corp. The 53 plants owned by these companies accounted for 67% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2010, 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 Exxon Mobil'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, 2010b). 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 (2010a), the United States operated 20% of world refining capacity, but had almost 39% of sulfur recovery capacity at refineries.

According to data from the National Petrochemical & Refiners Association (2011, p. 3), U.S. refining capacity rose by more than 4% from 2004 through 2010 and by more than 7% from 2000 through 2010, without building any new refineries. In 2010, U.S. refinery capacity was 18 million barrels per day. Overall U.S. refinery capacity increased by 153,000 barrels per day (bbl/d) in 2010; reaching a 5-year high. 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.

In June, PBF Energy Co. Ltd. completed its purchase of the Delaware City, DE, refinery from Valero at a cost of \$200 million. The 211,000-bbl/d refinery was closed by Valero in late 2009 as a result of poor economic conditions. PBF began maintenance work at the refinery and planned to restart it in 2011 (Sulphur, 2010j).

Western Refining Inc. idled its Yorktown, VA, refinery in September because of weak refining margins on the east coast. The company planned to continue operations at its products terminal and storage facility and supply the region with finished products. Restarting of the 70,800-bbl/d refinery was possible, if market conditions improved (Western Refining Inc., 2010).

During 2010, expansion and improvement projects were underway or in the planning stages at 11 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. One new Texas sulfur recovery plant was completed in 2010, but most were expected to be completed between 2011 and 2015 (Sulphur, 2011).

**Byproduct Sulfuric Acid.**—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 9% of total domestic production of sulfur in all forms and totaled the equivalent of 791,000 t of elemental sulfur. The portion of total sulfur product represented by byproduct sulfuric acid increased and the total quantity produced increased by about 6% (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 89% 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.

Freeport McMoRan proceeded with its \$150 million project to build a 1,450-metric-ton-per-day (t/d) sulfur-based sulfuric acid plant at its copper operation in Safford, AZ. The project had been put on hold in December 2008 as a result of the economic conditions in the copper industry and the downturn in the U.S. economy. The plant was expected to use sulfur brought by rail to a transport facility northwest of Stafford and then trucked to the plant. This plant was expected to use about 200,000 t/yr of sulfur (North America Sulphur Review, 2010). The project was expected to be completed within a year because much of the preliminary work had already begun (Sulphur, 2010i).

## Consumption

Apparent domestic consumption of sulfur in all forms was 19% higher than that of 2009 (table 5). Of the sulfur consumed, 68% was obtained from domestic sources as elemental sulfur (61%) and byproduct acid (7%) compared with 79% in 2009, 64% in 2008, 69% in 2007, and 69% in 2006. The remaining

32% was supplied by imports of recovered elemental sulfur (26%) and sulfuric acid (6%). The USGS collected end-use data on sulfur and sulfuric acid according to the standard industrial classification of industrial activities (table 6).

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The leading sulfur end use, sulfuric acid, represented 70% 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 90% of the total sulfur consumption. Some identified sulfur end uses were included in the “Unidentified” category because these data were proprietary. 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 10%, and total reported sulfur consumption decreased by 10%. These reported decreases in consumption can be attributed to the 9% decrease in petroleum refining and decreases in other chemical products. 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 6.71 Mt compared with 6.65 Mt in 2009 with an increase only for phosphatic fertilizers. Based on export data reported by the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased by about 7% to 4.2 Mt. More than 50% of domestic fertilizer production typically is exported; in 2010 about 50% was exported.

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 9% from that of 2009. Demand for sulfuric acid in copper ore leaching, which was the third ranked end use, increased by 10%.

The U.S. Census Bureau (2011) also reported that 2.1 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 164,000 t, 29% less than those of 2009 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 5-day supply, compared with a 9-day supply in 2009. Final stocks in 2010 represented 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

Increased demand for sulfur during 2010 resulted in higher prices. Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was estimated to be \$70.48 per metric ton, which was about 40 times greater than that of 2009. The increased value reported by producers correlated with the trends in prices recorded in trade publications.

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at \$27 per ton. In February, prices increased to \$82 per ton. In May, prices again increased to \$132 per ton, but decreased in August to \$86 per ton. Prices remained at that level until end of October, when they increased to \$145 per ton. The Tampa contract price remained at that level through the end of 2010, and additional price increases were expected in 2011.

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 2010, U.S. West Coast prices varied from \$0 per ton to \$90 per ton. 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 2010.

Even though prices vary by location, provider, and type, the Abu Dhabi National Oil Co.’s (ADNOC) price is recognized as an indicator of world sulfur price trends. In 2010, the ADNOC contract 2010 price averaged nearly \$150 per ton, with the lowest price of \$65 per ton in July and the highest price of \$210 per ton in March (North America Sulphur Review, 2011b).

## Foreign Trade

Strong domestic demand during much of the year resulted in exports from the United States, including the U.S. Virgin Islands, remained about the same in quantity but increased by 108% in value compared with those of 2009. The average unit value of export material was \$119 per ton, an increase of 105% from \$58 in 2009 (table 7). The leading destination for this material was Brazil, followed by, in descending quantity, China, 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 710,000 t, or 49% of total U.S. exports. Exports from the Gulf Coast were 570,000 t, or 39% of the U.S. total.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by about 1.5 Mt. Recovered elemental sulfur from Canada, Mexico, and Venezuela delivered to U.S. terminals and consumers in the liquid phase furnished almost 93% of U.S. sulfur import requirements. Total elemental sulfur imports were 74% greater in quantity than those of 2009, and higher prices for imported material resulted in the value being about three times that of 2009. Imports from Canada, mostly by rail, were estimated to be 62% higher than those of 2009, waterborne shipments from Mexico were twice as high, and waterborne imports from Venezuela were estimated to have decreased by 71%. Canada was the source of an estimated 79% of elemental sulfur imports, and Mexico supplied 13% (table 9).

In addition to elemental sulfur, the United States had significant trade in sulfuric acid. Sulfuric acid exports were 15% lower than those of 2009 (table 8). Acid imports were about 10 times exports (table 10). Canada and Mexico were the sources of 64% 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 67% greater than that of 2009, and the value of imported sulfuric acid decreased by about 5%.

## 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 2010 (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 89% of world pyrite production.

Of the 27 countries listed in table 11 that produced more than 500,000 t of sulfur, 16 obtained the majority of their production as recovered elemental sulfur. These 27 countries produced 94% of the total sulfur produced worldwide. In 2010, about 31 Mt of elemental sulfur was traded globally. The leading exporters were, in decreasing order of tonnage, Canada, Russia, Kazakhstan, Saudi Arabia, Abu Dhabi, the United States, Japan, Iran, and Qatar, 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).

Increased demand combined with lower than projected supply resulted in a balance between consumption and supply in 2010. Prices were lowest at the beginning of 2010 and increased toward the end of 2010. International prices for 2010 averaged higher than those in the United States. Sulfur imports increased in some of the main sulfur consuming countries, except China whose imports in 2009 exceeded demand. China had stock carryovers into 2010.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was about 23% higher than that of 2009. Recovered elemental sulfur production increased slightly and byproduct sulfuric acid production increased by about 6% compared with those of 2009. Globally, production of sulfur from pyrites decreased slightly. Pyrites are a less attractive alternative to elemental sulfur for sulfuric acid production. The environmental remediation costs of mining pyrites are onerous, and additional costs are incurred when using this less environmentally friendly raw material to produce sulfuric acid.

**Canada.**—Ranked third in the world in sulfur production, Canada was the leading sulfur and sulfuric acid exporter. In 2010, sulfur production in Canada was 3% lower than it was in 2009. 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 production from natural gas processing declined by 7% in 2010, and production from oil sands was slightly higher in 2010 than in 2009 (North America Sulphur Review, 2011a).

Canada's sulfur production was expected to remain stable over the medium term and may increase during 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).

A report from Alberta's Energy Resources Conservation Board (ERCB) published in 2011 showed that sulfur emissions in 2010 from Alberta's natural gas processing plants declined by 59% from levels in 2000 and 1% from those of 2009. Sulfur emissions declined as the result of improved sulfur recovery technology at the plants and because gas production declined as

resources became 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, 2011, p. 6).

An estimated 400,000 t of sulfur was added to Canada's stockpiles in 2010. Stocks increased to about 11.9 Mt in Alberta in 2010 (North America Sulphur Review, 2011c). More than 8 Mt of the sulfur stocks 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).

**Chile.**—Outotec Oyj (Finland) signed a contract with Corporación Nacional Del Cobre de Chile (Codelco) to design and deliver a copper concentrate roasting plant, gas cleaning system, and sulfuric acid plant for Codelco's new Mino Ministro Hales Mine close to Calama, in northern Chile. The \$160 million plant would treat up to 555,000 t/yr of copper concentrate and produce approximately 250,000 t/yr of sulfuric acid. The plant was expected to be commissioned by 2012 (Sulphur, 2010a).

**China.**—China was the leading producer of sulfur in all forms. It also was the world's leading producer of pyrites, with about 46% of its sulfur in all forms coming from that source. The country was the leading sulfur importer, with 10.1 Mt in 2010 (International Fertilizer Industry Association, 2011). Imports represented 76% 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.

In December 2009, the Chinese Government released its 2010 tariff rates for many phosphate fertilizers to discourage exports during periods of high domestic demand. The surcharge for the phosphate fertilizers would be 110% during January to May and October to December, and 7% during June to September (Fertilizer Week America, 2009). The export tariff rates were expected to reduce buying activity by China, the largest sulfur market, and reduce prices. However, the price of sulfur was not affected (North America Sulphur Review, 2011b).

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 (Sulphur, 2008). China has begun to build more efficient, less polluting coal-fired powerplants.

**India.**—Essar Oil Ltd. was to expand capacity at its Vadinar refinery in Gujarat to 360,000 bbl/d from 210,000 bbl/d at a cost of \$1.73 billion. Sulfur production from the refinery was expected to increase to 480,000 to 540,000 t/yr (Sulphur, 2010b).

Noraz Morarji Ltd. received approval from the Government of India to build a \$15.3 million sulfuric acid, downstream chemicals, and boron products plant at Dahej. The plant would have the

capacity to produce 130,000 t/yr of sulfuric acid, oleum, and liquid sulfur trioxide, and 24,000 t/yr of boron products (Sulphur, 2010c).

**Jordan.**—Jordan Phosphate Mines Co. signed a \$625 million contract with SNC-Lavalin Group to construct a plant to produce 1,500 t/d of phosphoric acid and 4,500 t/d [1.5 million metric tons per year (Mt/yr)] of sulfuric acid. Construction of the project, in El Eshidiya, began in 2010 and was expected to be completed by 2012 (Sulphur, 2010d).

**Kazakhstan.**—Kazphosphate began construction of a 600,000-t/yr sulfuric acid plant at Taraz city in southern Kazakhstan. The \$57 million project was expected to be completed by 2012 (Sulphur, 2010e).

**Mexico.**—Mexichem S.A.B. de C.V. reopened the Jaltipan sulfur mine in Veracruz State in May. The Frasch sulfur mine had been closed in 1992, although salt production continued at the site. Mexichem planned to operate the Jaltipan mine at a capacity of 210,000 t/yr sulfur. The Jaltipan salt and sulfur dome had proven reserves of 10 Mt of sulfur (Sulphur, 2010f). Sulfur production data for 2010 were not available.

## Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.6 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 result of refinery upgrades. Projects that had been announced before or during 2010 had the potential to add sulfur recovery capacity of about 20 Mt/yr by 2015, if all were completed on proposed schedules (Sulphur, 2011). In general, production from natural gas operations was expected to increase from that of 2010 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, 2011b).

Worldwide recovered sulfur output was expected to increase significantly. In 2009 and 2010, production of sulfur 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 new 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. Natural gas continued to be the fuel of choice in many regions of the world in the electric power and industrial sectors, in part because of its lower carbon intensity compared with coal and oil, which makes it an attractive fuel source in countries where governments are implementing policies to reduce greenhouse gas emissions. Some of the future gas production, however, is expected to come from unconventional natural gas resources such as tight gas, shale gas, and coal bed methane (U.S. Energy Administration, 2011a, p. 43–44). Use of unconventional gas sources will certainly affect the sulfur supply outlook for the future as these gases have low sulfur content.

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. Worldwide, the outlook for byproduct acid was more predictable. 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 (Sulphur, 2005). 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. Smelter production in the United States has decreased by 40% since 2000; during the same period, Chinese smelter acid production has more than doubled. Additional smelter capacity was expected in Chile, India, Kazakhstan, and Peru (Sulphur, 2010g).

Frasch sulfur and pyrites production, however, has little chance of significant long-term increases. In 2010, Frasch sulfur production remained the same as that of 2009. 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. The only potential increase in Frasch production is from Mexichem's Jaltipan sulfur mine. 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 for 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 11 countries; facilities were planned in Africa, Asia, Latin America, and Kazakhstan (Heffer and Prud'homme, 2011). Overall, one-half of all sulfur consumption (in all forms) is used for phosphate fertilizer production.

Industrial sulfur consumption has some prospects for growth, but not enough to consume all projected surplus. Solvent extraction-electrowinning copper projects that consume large quantities of sulfur are under development in Chile, China, India, Kazakhstan, and Peru during the next few years. Smelter acid represents almost one-third of sulfuric acid production (Sulphur, 2010g).

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<sub>2</sub> emissions and does not require water to manufacture. However, when sulfur prices are high, sulfur is less attractive for unconventional applications where low-cost raw materials are an important factor. In 2010, the Middle East had the most active interest in the potential use of sulfur as a binder or extender for high performance concrete and asphalt mixture (Sulphur, 2010h).

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<sup>1</sup>

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

	2006	2007	2008	2009	2010
United States:					
Quantity:					
Production:					
Recovered <sup>2</sup>	8,390	8,280	8,550	8,190	8,290
Other	674	817	753	749	791
Total <sup>c</sup>	9,060	9,100	9,300	8,940	9,080
Shipments:					
Recovered <sup>2</sup>	8,290	8,310	8,530	8,110	8,350
Other	674	817	753	749	791
Total	8,960	9,130	9,280	8,860	9,140
Exports:					
Elemental <sup>3</sup>	635	922	953	1,430	1,450
Sulfuric acid	81	110	86	83	71
Imports:					
Elemental <sup>e</sup>	2,950	2,930	3,000	1,700	2,950
Sulfuric acid	802	857	1,690	413	690
Consumption, all forms <sup>4</sup>	12,000	11,900	12,900	9,460	11,300
Stocks, December 31, producer, recovered	221	187	211	232	167
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Recovered <sup>c, 2</sup>	272,000	303,000	2,250,000	14,000	586,000
Other	64,700	45,200	110,000	87,500 <sup>f</sup>	92,400
Total	337,000	349,000	2,360,000	101,000 <sup>f</sup>	678,000
Exports, elemental <sup>5</sup>	437,000	84,800	272,000	82,200	171,000
Imports, elemental	70,400	79,400	753,000	54,100	214,000
Price, elemental, f.o.b. mine or plant <sup>e</sup> dollars per metric ton	32.85	36.49	264.04	1.73	70.16
World, production, all forms (including pyrites)	67,000 <sup>f</sup>	67,600 <sup>f</sup>	68,100 <sup>f</sup>	66,600 <sup>f</sup>	68,100

<sup>c</sup>Estimated. <sup>f</sup>Revised.

<sup>1</sup>Data are rounded to no more than three significant digits except prices; may not add to totals shown.

<sup>2</sup>Includes U.S. Virgin Islands.

<sup>3</sup>Includes exports from the U.S. Virgin Islands to foreign countries.

<sup>4</sup>Consumption is calculated as shipments minus exports plus imports.

<sup>5</sup>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<sup>1</sup>

(Thousand metric tons and thousand dollars)

State	2009			2010		
	Production	Shipments		Production	Shipments	
		Quantity	Value <sup>e</sup>		Quantity	Value <sup>e</sup>
Alabama	268	264	-4,490	259	258	25,100
California	1,010	1,000	4,280	1,050	1,100	60,800
Illinois	457	457	-1,160	458	457	28,500
Louisiana	1,330	1,370	10,300	1,260	1,240	89,400
Michigan and Minnesota	35	35	-679	W	W	W
New Mexico	25	25	388	25	25	734
Ohio	133	133	460	126	125	13,000
Texas	2,900	2,860	4,450	3,100	3,100	233,000
Washington	125	126	-284	139	138	5,890
Wyoming	656	668	3,600	624	625	29,100
Other <sup>2</sup>	1,250	1,170	-2,880	1,250	1,290	99,700
Total	8,190	8,110	14,000	8,290	8,350	586,000

<sup>e</sup>Estimated. W Withheld to avoid disclosing company proprietary data; included in "Other."

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>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<sup>1</sup>

(Thousand metric tons)

District and source	2009		2010	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	168	166	136	136
Natural gas	13	13	13	13
Total	181	179	150	149
PAD 2:				
Petroleum and coke	945	932	1,010	1,020
Natural gas	28	28	23	23
Total	973	960	1,040	1,040
PAD 3: <sup>2</sup>				
Petroleum and coke	4,580	4,580	4,680	4,660
Natural gas	546	485	486	509
Total	5,120	5,060	5,160	5,170
PAD 4 and 5:				
Petroleum and coke	1,280	1,270	1,290	1,350
Natural gas	627	638	647	648
Total	1,910	1,910	1,940	2,000
Grand total	8,190	8,110	8,290	8,350
Of which:				
Petroleum and coke	6,970	6,950	7,120	7,150
Natural gas	1,220	1,160	1,170	1,190

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Includes the U.S. Virgin Islands.

TABLE 4  
BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES<sup>1</sup>

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2009	2010
Copper <sup>2</sup>	671	704
Zinc, lead, and molybdenum <sup>3</sup>	79	87
Total:		
Quantity	749	791
Value	87,500 <sup>r</sup>	92,400

<sup>r</sup>Revised.

<sup>1</sup>May include acid produced from imported raw materials. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Excludes acid made from pyrites concentrates.

<sup>3</sup>Excludes acid made from native sulfur.

TABLE 5  
CONSUMPTION OF SULFUR IN THE UNITED STATES<sup>1</sup>

(Thousand metric tons of sulfur content)

	2009	2010
Elemental sulfur:		
Shipments <sup>2</sup>	8,110	8,350
Exports	1,430	1,450
Imports <sup>e</sup>	1,700	2,950
Total	8,380	9,850
Byproduct sulfuric acid:		
Shipments	749	791
Exports <sup>3</sup>	83	71
Imports <sup>3</sup>	413	690
Total	1,080	1,410
Grand total	9,460	11,300

<sup>e</sup>Estimated.

<sup>1</sup>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.

<sup>2</sup>Includes the U.S. Virgin Islands.

<sup>3</sup>May include sulfuric acid other than byproduct.

TABLE 6  
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE<sup>1</sup>

(Thousand metric tons of sulfur content)

SIC <sup>3</sup>	End use	Elemental sulfur <sup>2</sup>		Sulfuric acid (sulfur equivalent)		Total	
		2009	2010	2009	2010	2009	2010
102	Copper ores	--	--	363	400	363	400
1094	Uranium and vanadium ores	--	--	2	--	2	--
10	Other ores	--	--	112	62	112	62
26, 261	Pulpmills and paper products	W	W	188	79	188	79
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products <sup>4</sup>	W	W	286	31	286	31
281	Other inorganic chemicals	W <sup>r</sup>	W	99	57	99 <sup>r</sup>	57
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	64	6	64	6
2823	Cellulosic fibers including rayon	--	--	7	--	7	--
284	Soaps and detergents	-- <sup>r</sup>	--	3	2	3	2
286	Industrial organic chemicals	--	--	36	9	36	9
2873	Nitrogenous fertilizers	--	--	161	16	161	16
2874	Phosphatic fertilizers	--	--	5,430	5,700	5,430	5,700
2879	Pesticides	--	--	9	12	9	12
287	Other agricultural chemicals	1,000	952	44	30	1,050	982
2892	Explosives	--	--	10	11	10	11
2899	Water-treating compounds	--	--	64	26	64	26
28	Other chemical products	--	--	250	21	250	21
29, 291	Petroleum refining and other petroleum and coal products	2,360	2,050	283	368	2,650	2,410
331	Steel pickling	--	--	8	11	8	11
33	Other primary metals	--	--	5	--	5	--
3691	Storage batteries (acid)	--	--	28	30	28	30
	Exported sulfuric acid	--	--	197	3	197	3
	Total identified	3,370	3,000	7,650	6,880	11,000	9,880
	Unidentified	489	482	96 <sup>r</sup>	96	585	578
	Grand total	3,860	3,480	7,740	6,980	11,600	10,500

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

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Does not include elemental sulfur used for production of sulfuric acid.

<sup>3</sup>Standard industrial classification.

<sup>4</sup>No elemental sulfur was used in inorganic pigments, paints, and allied products.



TABLE 7  
U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY<sup>1</sup>

(Thousand metric tons and thousand dollars)

Country	2009		2010	
	Quantity	Value	Quantity	Value
Brazil	383	15,600	632	58,000
Canada	29	5,730	58	8,620
China	731	39,800	317	48,900
Mexico	127	8,030	169	22,100
Morocco	33	1,610	34	2,890
Other	122	11,400	235	30,800
Total	1,430	82,200	1,450	171,000

<sup>1</sup>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<sub>2</sub>SO<sub>4</sub>), BY COUNTRY<sup>1</sup>

Country	2009		2010	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	212,000	\$14,300	155,000	\$12,500
China	2,750	371	4,670	1,060
Dominican Republic	649	149	2,530	363
El Salvador	469	74	894	112
Germany	494	102	31	69
Greece	505	60	331	38
Hong Kong	21	57	46	93
Ireland	1,180	1,500	956	845
Israel	2,680	2,340	1,760	2,270
Korea, Republic of	79	30	46	23
Mexico	3,810	1,150	14,700	2,390
Netherlands Antilles	3,040	539	2,000	2,000
Nigeria	1	9	35	4
Philippines	469	313	1,540	661
Poland	825	94	947	108
Singapore	66	143	2,180	591
Taiwan	843	205	138	161
Thailand	463	95	693	88
Trinidad and Tobago	4,760	543	10,500	858
Venezuela	16,400	1,070	8,440	577
Other	2,230	767	8,100	1,590
Total	254,000	23,900	215,000	26,400

<sup>1</sup>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<sup>1</sup>

(Thousand metric tons and thousand dollars)

Country	2009		2010	
	Quantity	Value <sup>2</sup>	Quantity	Value <sup>2</sup>
Canada	1,430	45,800	2,320 <sup>e</sup>	122,000
Mexico	125	2,540	378	37,400
Venezuela	140	2,400	41	4,200
Other	6	3,390	211	50,200
Total	1,700	54,100	2,950 <sup>e</sup>	214,000

<sup>e</sup>Estimated.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Declared customs valuation.

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

TABLE 10  
U.S. IMPORTS OF SULFURIC ACID (100% H<sub>2</sub>SO<sub>4</sub>), BY COUNTRY<sup>1</sup>

Country	2009		2010	
	Quantity (metric tons)	Value <sup>2</sup> (thousands)	Quantity (metric tons)	Value <sup>2</sup> (thousands)
Bulgaria	29,100	\$481	--	--
Canada	821,000	118,000	1,150,000	\$79,100
China	392	386	91,000	8,880
Egypt	--	--	11,500	1,560
Finland	39,300	4,040	1,000	657
Germany	--	--	133,000	3,920
Japan	20,000	477	60,900	3,640
Korea, Republic of	37,000	4,160	17,000	2,040
Mexico	108,000	4,750	199,000	11,100
Peru	66,700	2,300	--	--
Poland	30,200	434	79,300	4,200
Sweden	15,600	742	27,600	696
Other	98,200	10,300	336,000	23,100
Total	1,260,000	146,000	2,110,000	139,000

-- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>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<sup>1,2</sup>

(Thousand metric tons)

Country and source <sup>3</sup>	2006	2007	2008	2009	2010
Australia, byproduct: <sup>c</sup>					
Metallurgy	880	890	880	870	880
Petroleum	58	60	58	60	60
Total	938	950	938	930	940
Brazil:					
Frasch	21	22	22 <sup>e</sup>	22 <sup>e</sup>	22 <sup>e</sup>
Byproduct:					
Metallurgy	298	322	322	322	322 <sup>e</sup>
Petroleum	117	136	136	136	136
Total	436	480	480	480	480
Canada, byproduct:					
Metallurgy	1,176	1,167	1,148 <sup>r</sup>	890 <sup>e</sup>	900 <sup>e</sup>
Natural gas, petroleum, oil sands	7,906	7,622	7,008 <sup>r</sup>	6,577	6,355
Total	9,082	8,789	8,156 <sup>r</sup>	7,467	7,255
Chile, byproduct, metallurgy	1,641	1,569	1,573	1,653 <sup>r</sup>	1,676
China: <sup>c</sup>					
Elemental	950	960	960	1,000	1,100
Pyrites	3,810	4,200	4,300	4,370	4,400
Byproduct, metallurgy	3,000	3,300	3,350	4,000	4,100
Total	7,760	8,460	8,610	9,370	9,600
Finland: <sup>c</sup>					
Pyrites	250	250	250	250	225
Byproduct:					
Metallurgy	300	300	300	300	300
Petroleum	65	65	65	65	65
Total	615	615	615	615	590
France, byproduct: <sup>c</sup>					
Natural gas and petroleum	616 <sup>4</sup>	606 <sup>4</sup>	605	605	605
Unspecified	750	700	700	700	700
Total	1,366 <sup>4</sup>	1,306 <sup>4</sup>	1,310	1,310	1,310
Germany, byproduct:					
Metallurgy	2,437 <sup>r</sup>	2,454 <sup>r</sup>	2,458 <sup>r</sup>	2,137 <sup>r</sup>	2,458
Natural gas and petroleum	1,686	1,637	1,709	1,623	1,447
Total	4,124 <sup>r</sup>	4,091 <sup>r</sup>	4,167 <sup>r</sup>	3,760 <sup>r</sup>	3,905
India: <sup>c</sup>					
Pyrites	32	32	32	32	31
Byproduct:					
Metallurgy	600	590	600	590	600
Natural gas and petroleum	540	530	540	530	540
Total	1,170	1,150	1,170	1,150	1,170
Iran, byproduct: <sup>c</sup>					
Metallurgy	65	70	70	70	80
Natural gas and petroleum	1,400	1,500	1,500	1,500	1,700
Total	1,470	1,570	1,570	1,570	1,780

See footnotes at end of table.

TABLE 11—Continued  
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE <sup>1,2</sup>

(Thousand metric tons)

Country and source <sup>3</sup>	2006	2007	2008	2009	2010
Italy, byproduct: <sup>c</sup>					
Metallurgy	90	90	90	90	90
Petroleum	650	650	650	650	650
Total	740	740	740	740	740
Japan, byproduct:					
Metallurgy	1,343	1,250 <sup>e</sup>	1,300	1,350	1,400
Petroleum	1,950	1,966	2,034	1,864 <sup>r</sup>	1,892
Total	3,293	3,216	3,334	3,214 <sup>r</sup>	3,292
Kazakhstan, byproduct: <sup>c</sup>					
Metallurgy	300	300	300	300	300
Natural gas and petroleum	1,700	1,661 <sup>4</sup>	1,733 <sup>4</sup>	1,700	1,700
Total	2,000	1,961	2,033	2,000	2,000
Korea, Republic of, byproduct: <sup>c</sup>					
Metallurgy	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	--
Petroleum	660 <sup>r</sup>	670 <sup>r</sup>	600 <sup>r</sup>	660 <sup>r</sup>	660
Total	660 <sup>r</sup>	670 <sup>r</sup>	600 <sup>r</sup>	660 <sup>r</sup>	660
Kuwait, byproduct, natural gas and petroleum <sup>c</sup>	830 <sup>r</sup>	830	800 <sup>r</sup>	830	830
Mexico, byproduct:					
Metallurgy <sup>c</sup>	650	550	700	700	700
Natural gas and petroleum	1,074	1,026	1,041	1,114 <sup>r</sup>	1,110
Total	1,724	1,576	1,741	1,814 <sup>r</sup>	1,810
Netherlands, byproduct: <sup>c</sup>					
Metallurgy	130	130	130	130	130
Petroleum	400	400	400	400	400
Total	530	530	530	530	530
Poland: <sup>e,5</sup>					
Native	800	834	762	263 <sup>r,4</sup>	517 <sup>4</sup>
Byproduct:					
Natural gas	20	23	21	25 <sup>r</sup>	25
Petroleum	182	188	201 <sup>r</sup>	190 <sup>r</sup>	190
Total	1,000	1,050	984 <sup>r</sup>	478 <sup>r</sup>	732
Qatar, byproduct, natural gas	360 <sup>e</sup>	360 <sup>e</sup>	527	658	1,124
Russia: <sup>e,6</sup>					
Native	50	50	50	50	50
Pyrites	200	200	200	200	200
Byproduct:					
Metallurgy	700	800	820	820	820
Natural gas	6,000	6,000	6,100	6,000	6,000
Total	6,950	7,050	7,170	7,070	7,070
Saudi Arabia, byproduct, all sources	2,907	3,089	3,163	3,200 <sup>e</sup>	3,300 <sup>e</sup>
South Africa:					
Pyrites, S content, from gold mines	68	71	61	60	30
Byproduct:					
Metallurgy, copper, platinum, zinc plants	231	236	187	175 <sup>r,e</sup>	160 <sup>e</sup>
Petroleum	343	335	323	300 <sup>r,e</sup>	275 <sup>e</sup>
Total	643	642	571	535 <sup>r,e</sup>	465 <sup>e</sup>

See footnotes at end of table.



TABLE 11—Continued  
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE<sup>1,2</sup>

(Thousand metric tons)

Country and source <sup>3</sup>	2006	2007	2008	2009	2010
Spain, byproduct: <sup>c</sup>					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	500	500	500	500	500
Petroleum	117 <sup>4</sup>	136 <sup>4</sup>	136 <sup>4</sup>	136 <sup>4</sup>	136
Total	618	637	637	637	637
United Arab Emirates, byproduct, natural gas and petroleum <sup>c</sup>	1,950	1,950	2,175 <sup>4</sup>	2,000	1,763 <sup>4</sup>
United States, byproduct:					
Metallurgy	674	817	753	749	791
Natural gas	1,430	1,280	1,300	1,220	1,170
Petroleum	6,960	7,000	7,240	6,970	7,120
Total	9,060	9,100	9,300	8,940	9,080
Uzbekistan, byproduct: <sup>c</sup>					
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 <sup>c</sup>	800	800	800	800	800
Other <sup>c</sup>	3,820 <sup>r</sup>	3,880 <sup>r</sup>	3,890 <sup>r</sup>	3,690 <sup>r</sup>	4,020
Of which:					
Native	218 <sup>r</sup>	218 <sup>r</sup>	228 <sup>r</sup>	209	215
Pyrites	167 <sup>r</sup>	190 <sup>r</sup>	205 <sup>r</sup>	106	64
Unspecified	1,150	1,150 <sup>r</sup>	1,160 <sup>r</sup>	1,190 <sup>r</sup>	1,170
Byproduct:					
Metallurgy	1,020 <sup>r</sup>	1,030 <sup>r</sup>	1,020 <sup>r</sup>	1,000 <sup>r</sup>	1,000
Natural gas <sup>7</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	--
Other—Continued: <sup>c</sup>					
Of which:					
Byproduct—Continued:					
Natural gas and petroleum, undifferentiated <sup>8</sup>	482 <sup>r</sup>	472	428	423 <sup>r</sup>	461
Petroleum	780 <sup>r</sup>	820 <sup>r</sup>	845 <sup>r</sup>	759 <sup>r</sup>	1,110
Grand total	67,000 <sup>r</sup>	67,600 <sup>r</sup>	68,100 <sup>r</sup>	66,600 <sup>r</sup>	68,100
Of which:					
Frasch	21	22	22	22	22
Native	2,020 <sup>r</sup>	2,060 <sup>r</sup>	2,000 <sup>r</sup>	1,520	1,880
Pyrites	4,530 <sup>r</sup>	4,940 <sup>r</sup>	5,050 <sup>r</sup>	5,020 <sup>r</sup>	4,950
Unspecified	4,810 <sup>r</sup>	4,940 <sup>r</sup>	5,020 <sup>r</sup>	5,090 <sup>r</sup>	5,170
Byproduct:					
Coal, lignite, gasification <sup>c</sup>	1	1	1	1	1
Metallurgy	16,200 <sup>r</sup>	16,500 <sup>r</sup>	16,700 <sup>r</sup>	16,800 <sup>r</sup>	17,400
Natural gas <sup>7</sup>	7,810	7,670	7,950	7,900	8,320
Natural gas and petroleum, undifferentiated <sup>8</sup>	19,300 <sup>r</sup>	19,000 <sup>r</sup>	18,700 <sup>r</sup>	18,100 <sup>r</sup>	17,700
Petroleum	12,300 <sup>r</sup>	12,400 <sup>r</sup>	12,700 <sup>r</sup>	12,200 <sup>r</sup>	12,700

<sup>c</sup>Estimated. <sup>r</sup>Revised. -- Zero.

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

<sup>2</sup>Table includes data available through September 28, 2011.

TABLE 11—Continued  
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE<sup>1,2</sup>

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<sup>3</sup>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 may not be the original source country of the crude product from which the sulfur is extracted.

<sup>4</sup>Reported figure.

<sup>5</sup>Government of Poland sources report total Frasch and native mined elemental sulfur output annually, undifferentiated.

<sup>6</sup>Sulfur is thought to be produced from Frasch and as a petroleum byproduct; however, information is inadequate to formulate estimates.

<sup>7</sup>Excludes “Ecuador, natural gas.”

<sup>8</sup>Includes “Ecuador, natural gas.”