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SULFUR

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Sulfur

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In 2012, the global demand for sulfur remained strong despite decreased phosphate fertilizer consumption worldwide. Global sulfur trade increased by about 3% compared with that in 2011 owing mainly to the increased demand for sulfur in China and Brazil (Prud'homme, 2013, p. 50).

The United States ranked second in world sulfur production following China (table 11). 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; an estimated 29.0 million metric tons (Mt), which is equivalent to about 9.5 Mt of elemental sulfur, was produced in 2012, about a 3% decrease from that of 2011 (International Fertilizer Industry Association, 2013b, p. 9).

In 2012, domestic production and shipments of sulfur in all forms were slightly higher than those of 2011 (table 1). Elemental sulfur recovered at petroleum refineries was 4% higher than it was in 2011, and sulfur recovered from natural gas operations decreased by 10%. Producers' stocks decreased by 25%, accounting for less than 1% of shipments. Byproduct sulfuric acid production and shipments decreased by 19%. Apparent consumption of sulfur in all forms decreased by 6%. Imports of elemental sulfur and sulfuric acid combined decreased by 7% and exports increased by 34%. The average unit value of recovered sulfur in 2012 was 23% less than that of 2011, resulting in the value of total elemental sulfur shipments decreasing by 20% compared with the 2011 value of shipments. The total value of byproduct sulfuric acid shipments decreased by about 4% (table 1).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; for 2012, global sulfur production was virtually unchanged (table 11). 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 6%. In the few countries where pyrites remain an important raw material for sulfuric acid production, sulfur production from pyrites increased slightly.

Since 2005, between 81% 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, recovered elemental sulfur or byproduct sulfuric acid, increasing 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 by 4% from that of 2011; typically, about 50% was used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur increased about 3% from the levels reported in 2011. Worldwide inventories of elemental sulfur were tight owing to the continued demand for sulfur; some of the demand was met by drawing down stocks in Canada and Kazakhstan (Prud'homme, 2012, p. 40).

Legislation and Government Programs

On August 1, 2012, the California Ocean-Going Vessels Fuel Regulation, requiring ships to use cleaner, low-sulfur marine distillate fuel in main engines, auxiliary engines, and boilers, was revised to reduce the maximum allowable fuel sulfur content from 1.5% to 1.0% sulfur. These mandatory fuel standards affect ocean-going vessels within California waters and within 44 kilometers (24 nautical miles) of the California coastline (California Air Resources Board, 2012).

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 2012, production and shipments were slightly higher than those of 2011. Lower prices and decreased demand for sulfur resulted in the value of recovered shipments being 20% lower than that of 2011. For 2012, on average, U.S. petroleum refineries operated at 88.7% of capacity, a 3% increase from that of 2011 (U.S. Energy Information Administration, 2013d).

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 39 companies at 103 plants in 25 States and 1 plant in the U.S. Virgin Islands (closed in February 2012). 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 2012, 15 produced between 50,000 and 100,000 t, 32 produced between 10,000 and 50,000 t, and 24 plants produced less than 10,000 t. By source, 88% of recovered elemental sulfur production came from petroleum refineries or satellite plants that treated refinery gases and coking plants; the remainder was produced at natural-gas-treatment plants (table 3).

The leading producers of recovered sulfur, all with more than 500,000 t of sulfur production were, in descending order of production, Exxon Mobil Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), Valero Energy Corp., Chevron Corp., Shell Oil Co., and Marathon Petroleum Corp. The 42 plants owned by these companies accounted for 56% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2012, 5 of the 20 largest oil refineries in the world, in terms of crude-processing capacity, were in the United States. In descending order of capacity, they were Exxon Mobil's Baytown, TX, refinery; Marathon's Garyville, LA, refinery; Exxon Mobil's Baton Rouge, LA, refinery; BP's Texas City, TX, refinery; and Citgo Petroleum Corp.'s Lake Charles, LA, refinery (Oil & Gas Journal, 2012b). 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 (2012a, p. 2), the United States operated 20% of world refining capacity, but had almost 40% of world sulfur recovery capacity at these refineries.

According to data from the U.S. Energy Information Administration (2013c), U.S. refining capacity rose slightly from 2009 through 2012, and capacity rose by about 5% from 2000 through 2011, without building any new refineries. In 2012, U.S. refinery capacity was 17.8 million barrels per day. Overall U.S. refinery capacity increased by about 500,000 barrels per day (bbl/d) in 2012 owing to the increase in refining capacity at the Motive Enterprises, LLC, Port Arthur, TX, refinery and the restart of the Monroe Energy, LLC, Trainer, PA, refinery. 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.

Hovensa LLC announced in January 2012, that it would commence shutdown of its 495,000-bbl/d refinery on St. Croix in the U.S. Virgin Islands in February. After the refinery shut down, it would operate as an oil storage terminal. Hovensa had recently upgraded its sulfur recovery facilities to a capacity of 1.5 million metric tons per year (Mt/yr). Losses at the refinery totaled $1.3 billion in the past 3 years owing to the weakness in demand for refined petroleum products following the global downturn, and the company was unable to compete with new refining capacity in emerging markets (Sulphur, 2012c).

Monroe Energy (a subsidiary of Delta Air Lines) reached an agreement with Phillips 66 Co. to acquire the Trainer refinery complex south of Philadelphia, PA. The Trainer refinery complex had a crude oil processing capacity of 185,000 bbl/d and processed mainly light, low-sulfur crude oil. Monroe acquired the refinery for $150 million and planned to spend $100 million to convert the existing infrastructure to maximize jet fuel production. In addition, Monroe received $30 million in State government assistance for job creation and infrastructure improvement (Delta Air Lines, 2012).

Sunoco, Inc. formed a joint venture with the Caryle Group to keep the 330,000-bbl/d refinery in Philadelphia, PA, in service. Plans were to upgrade the refinery and construct a high-speed train-unloading facility linking the refinery with North American crude supplies. The Pennsylvania State government would provide grants, reported to be worth $25 million, to help finance the refinery upgrade and rail facility (Oil & Gas Journal, 2012c).

During 2012, expansion and improvement projects were underway or in the planning stages at six refineries in the United States. In addition to increasing throughput capacity at the operations, upgrades were intended to increase the existing refineries' capabilities to process low-quality, high-sulfur crude oil, such as those from Canada's 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 sulfur recovery plant was completed in 2012, but most were expected to be completed between 2013 and 2014 (Sulphur, 2013).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 7% of total domestic production of sulfur in all forms and totaled the equivalent of 586,000 t of elemental sulfur. Byproduct sulfuric acid production decreased by 19% compared with that of 2011 (tables 1, 4). Three acid plants operated in conjunction with copper smelters, and two 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 92% 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 6% lower than that of 2012 (table 5). Of the sulfur consumed, 65% was obtained from domestic sources as elemental sulfur (60%) and byproduct acid (5%) compared with 64% in 2011, 67% in 2010, 79% in 2009, and 64% in 2008. The remaining 35% was supplied by imports of recovered elemental sulfur (27%) and sulfuric acid (8%). The USGS collected end-use data on sulfur and sulfuric acid according to the standard industrial classification (SIC) 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 66% 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 85% of the total sulfur consumption. Some identified sulfur end uses were included in the "Unidentified" category (table 6) 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 3%, and total reported sulfur consumption increased by 3%. The reported decrease in sulfuric acid consumption can be attributed to the 6% decrease in sulfur acid use in phosphate fertilizers. 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 3% to 7.26 Mt compared with 7.51 Mt in 2011 resulting from decreased consumption in 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 11% to 4.2 Mt. In 2012, about 45% of the domestic phosphate fertilizer production 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 slightly from that of 2011. Demand for sulfuric acid in copper ore leaching, which was the third ranked end use, increased slightly.

Production data for sulfuric acid produced as a result of recycling spent and contaminated acid from petroleum alkylation and other processes in 2012 were no longer available from the U.S. Census Bureau. 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 132,000 t, 25% less than those of 2011 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 4-day supply, which compares with a 5-day supply in 2011. Final stocks in 2012 represented 2% of the quantity held in inventories at the end of 1976, when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1980, p. 877). 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 minimal storage capacity.

Prices

Weaker demand for sulfur during 2012 resulted in lower prices than those of 2011. On the basis of value data reported to the USGS, the average unit value of shipments for all elemental sulfur was estimated to be $123.54 per metric ton, which was 23% less than that of 2011. The decreased unit value reported by producers correlated with the trends in prices recorded in trade publications.

Contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at $220 per ton. In February, prices decreased to $172 per ton. In May, prices increased to $180 per ton but decreased to $160 per ton by yearend.

Prices vary greatly on a regional basis. Tampa prices were usually the highest reported in the United States because of the large demand for sulfur in the central Florida area. At yearend, U.S. west coast prices ranged from $150 per ton to $155 per ton. Nearly all the sulfur produced in some regions, such as the west coast, was 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 2012.

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 2012, the ADNOC contract price averaged about $190 per ton, with the lowest price of $165 per ton in December and the highest price of $215 per ton in June (Fertilizer Week, 2013).

Foreign Trade

Strong world demand during much of the year resulted in exports from the United States, including the U.S. Virgin Islands, increasing by about 41% in quantity and increasing by 28% in overall value compared with those of 2011. The average unit value of export material was $198 per ton, a slight decrease from $203 in 2011 (table 7). The leading destination for this material was Brazil, followed by, in descending quantity, Mexico, Chile, and China. 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 1.0 Mt, or 56% of total U.S. exports. Exports from the Gulf Coast were 750,000 t, or 40% of the U.S. total.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by about 1.0 Mt. Recovered elemental sulfur from Canada, Mexico, and Venezuela delivered to U.S. terminals and consumers in the liquid phase furnished almost 100% of U.S. sulfur import requirements. Total elemental sulfur imports in 2012 were 10% less than those of 2011, and lower prices for imported material resulted in the value being about 21% less than that of 2011. Imports from Canada, mostly by rail, were estimated to be 10% less than those of 2011, waterborne shipments from Mexico were 21% higher, and waterborne imports from Venezuela were estimated to have increased by 16%. Canada was the source of an estimated 83% of elemental sulfur imports, and Mexico supplied 13% (table 9).

In addition to elemental sulfur, the United States trades in sulfuric acid. Sulfuric acid exports were 52% lower than those of 2011 (table 8). Acid imports were about 18 times greater than exports (tables 1, 10). Canada and Mexico were the sources of 86% of sulfuric 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 7% greater than that of 2011, and the value of imported sulfuric acid decreased by about 8%.

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 9% of the sulfur produced in all forms worldwide in 2012 (table 11).

Poland was the only country that produced more than 600,000 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 among the top producers whose primary sulfur source was pyrites. China accounted for 90% of world pyrite production.

Of the 15 countries listed in table 11 that produced more than 1 Mt of sulfur, 13 obtained the majority of their production as recovered elemental sulfur. These 15 countries produced 83% of the total sulfur produced worldwide. In 2012, about 32 Mt of elemental sulfur was traded globally. The leading exporters were, in decreasing order of tonnage, Canada, Russia, Kazakhstan, Saudi Arabia, the United Arab Emirates, Qatar, the United States, Iran, and Japan, all with more than 1 Mt of exports. The leading importer was China, by far, followed by, in decreasing order of tonnage, the United States, Morocco, India, Russia, Brazil, Mexico and Tunisia (International Fertilizer Industry Association, 2013a).

In 2012, sulfur consumption exceeded global production, even with lower demand in the phosphate fertilizer and industrial sectors. As a result, stocks in Canada and Kazakhstan were used to meet global needs (Prud'homme, 2012, p. 40). Prices were highest at the beginning of 2012 and decreased toward the end of 2012. International prices for 2012 averaged higher than those in the United States. Sulfur imports decreased in most of the main sulfur consuming countries, except China, which was the world's largest importer in 2012, with about 30% of the total.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was about 5% higher than that of 2011. Recovered elemental sulfur production and byproduct sulfuric acid production were about the same compared with those of 2011. Globally, production of sulfur from pyrites increased 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 fourth in the world in sulfur production, Canada was the leading sulfur and sulfuric acid exporter. In 2012, sulfur production in Canada was 5% lower than it was in 2011. About two-thirds of Canada's sulfur was recovered at natural gas and oil sands operations in Alberta, with some recovered from natural gas in British Columbia and from oil refineries in other parts of the country. Sulfur production from natural gas processing declined 16% in 2012, and production from oil sands was about 11% higher in 2012 than in 2011 (Stone, 2014).

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. Exploration for conventional natural gas came to a halt in 2012. Production from oil sands operations was expected to overtake natural gas processing, and sulfur recovered from petroleum refineries was expected to remain relatively stable. Canada was likely to remain a leader in world sulfur production. Byproduct acid production was expected to remain relatively stable.

The most current report from Alberta's Energy Resources Conservation Board (ERCB) showed that sulfur emissions in 2011 from Alberta's natural-gas-processing plants declined by 62% from levels in 2000 and by 7% from those of 2010. Sulfur emissions declined as the result of improved sulfur recovery technology at several plants and the closing of one plant in 2011. Although sulfur recovery increased as a percentage of gas processing, total sulfur recovery declined during the same period because of lower gas-processing volumes (Energy Resources Conservation Board, 2012, p. 6).

ERCB recorded a sulfur inventory of 11 Mt at yearend 2012. About 10 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. The lack of railway access is a major obstacle in the shipment of sulfur from oil sands production sites (Stone, 2014).

In June 2012, Sulphur in Diesel Fuel Regulations were amended by Environment Canada to establish maximum limits for sulfur in diesel fuel for use on-road, off-road, in rail (locomotive), vessels, and stationary engines. These limits applied to the production, imports, and sale of diesel fuel in Canada (Environment Canada, 2012).

Imperial Oil Ltd. revived its plan to complete a Can$2 billion expansion project of its Cold Lake oil sands operation in northeastern Alberta. The project would increase bitumen (a heavy black viscous oil) production by more than 40,000 bbl/d and was scheduled to be completed by yearend 2014 (Sulphur, 2012a).

China.—China was the leading producer of sulfur in all forms. It also was the world's leading producer of pyrites, with about 55% of its sulfur in all forms coming from that source. The country was the leading sulfur importer, with 11.1 Mt (International Fertilizer Industry Association, 2013a). Imports represented about 70% of elemental sulfur consumption in China, with the Middle East as the leading source of the imports, followed by Kazakhstan. Fertilizer production consumed about two-thirds of the sulfuric acid used in China.

In December 2012, the Chinese Government released its 2013 export tariff rates for phosphate fertilizers to discourage exports during periods of high domestic demand. The base rate of the low-tariff window (May 16 to October 15) was reduced to 5% from 7%, and the benchmark price was increased by about 3% for diammonium phosphate and reduced by about 9% for monoammonium phosphate. The tax rate for phosphate fertilizers during high-season would be lowered to 80% from 110% during January 1 to May 15 and October 16 to December 31 (Fertilizer Week, 2012).

Venezuela.—Global Engineering and Construction Group was awarded a contract by PdVSA Petróleo S.A. for the engineering, procurement, and construction management for the El Palito Refinery Expansion Project, near Puerto Cabello. The expansion would double the refinery's capacity to 280,000 bbl/d, include a 250-metric-ton-per-day sulfur recovery/tail gas treatment unit, and was expected to be completed by 2016 (Sulphur, 2012d).

Wilson Engineering, of China, and Republic of Korea's Hyundai Engineering were awarded a refinery engineering, procurement, and construction contract by PdVSA for expanding and upgrading the Puerto la Cruz refinery, near Barcelona. The upgrade would allow the refinery to process 210,000 bbl/d of extra-heavy Orinco crude, and was expected to be operational by 2016. The sulfur recovery would increase by about 200,000 t/yr (Sulphur, 2012d).

Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.5 Mt/yr, but increases are expected in upcoming years as expansions, upgrades, and new facilities at existing refineries are completed. The expansions would enable refiners to increase throughput of crude oil and to process higher sulfur crude oils; additional sulfur production would be a result of refinery upgrades. Projects that had been announced before or during 2012 have the potential to add sulfur recovery capacity of about 830,000 t/yr by 2014, if all are completed on proposed schedules (Sulphur, 2013). Production from natural gas operations is expected to increase from that of 2012 as more natural gas is recovered from shale formations, horizontal drilling, and hydraulic fracturing. More efficient, cost-effective drilling techniques, primarily in shale formations, are likely to spur development in U.S. natural gas production (U.S. Energy Information Administration, 2013b).

Worldwide recovered sulfur output is also expected to increase. In 2011 and 2012, production of sulfur was not enough to meet demand, but supply and demand are expected to be in balance in 2013 and 2014. Sulfur surpluses are expected in 2015, increasing thereafter as a result of increased production, especially from oil sands in Canada, from heavy-oil processors in Venezuela, and from eastern Europe, central Asia, and west Asia (primarily the countries of the United Arab Emirates, Saudi Arabia, and Turkmenistan) (Prud'homme, 2013).

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

World consumption of natural gas is expected to maintain strong growth, and sulfur recovery from that sector likely will continue to increase. 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 future gas production is expected to come from unconventional natural gas resources such as tight gas, shale gas, and coalbed methane (U.S. Energy Administration, 2013a). Use of unconventional natural gas sources in some areas of the world may affect the sulfur supply outlook for the future because these sources tend to have lower sulfur content. However, increased sulfur from sour gas processing in China, central Asia, and the Middle East is projected to more than compensate for the decrease in sulfur resulting from unconventional natural gas sources.

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. 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 acid production in the United States has decreased by 43% since 2000; during the same period, Chinese smelter acid production has more than tripled. Additional smelter capacity is expected in Brazil, India, Russia, and Zambia. Increased byproduct sulfuric acid product is expected to add another 6 to 7 Mt/yr of sulfur during the next 5 years (Sulphur, 2012b).

Frasch sulfur and pyrites production, however, has little chance of significant long-term increases. In 2012, Frasch sulfur production increased by 3% from that of 2011. Because of the continued increases in elemental sulfur recovery and byproduct sulfuric acid production for environmental reasons, discretionary sulfur has become increasingly less important as demonstrated by the lack of expansion in the Frasch sulfur industry. The Frasch process has become the high-cost process for sulfur production and any new projects would require sulfur prices to increase enough to justify the initial investment. Pyrites, with significant direct production costs, are 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 decrease likely will be pronounced when large operations are closed 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 is 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. Copper and nickel leaching are the major consumers of sulfuric acid, but uranium leaching is increasing as the demand increases for nuclear power (Sulphur, 2011).

From year to year, however, the use of sulfur directly or in compounds such 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. Major expansions of phosphate fertilizer production are expected at facilities in China, Morocco, and Saudi Arabia (Heffer and Prud'homme, 2013). Overall, one-half of all sulfur consumption (in all forms) is used for phosphate fertilizer production.

Less traditional uses for elemental sulfur have not increased. In the 1970s and 1980s, research 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 carbon dioxide (CO_2) 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 the near term, increased global production and continued demand will keep the sulfur market balanced. This is expected to be followed in the long term by a surplus worldwide. International sulfur trade is expected to increase significantly, driven by demand for sulfuric acid in industrial sectors (particularly new ore leaching operations) and a modest increase in demand for fertilizers.

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TABLE 1
SALIENT SULFUR STATISTICS[1]

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

		2008	2009	2010	2011	2012
United States:						
Quantity:						
Production:						
Recovered[2]		8,550	8,190	8,320 r	8,230	8,410
Other		753	749	791	720	586
Total e		9,300	8,940	9,110 r	8,950	9,000
Shipments:						
Recovered[2]		8,530	8,110	8,380 r	8,210	8,450
Other		753	749	791	720	586
Total		9,280	8,860	9,170 r	8,930	9,030
Exports:						
Elemental[3]		953	1,430	1,450	1,310	1,850
Sulfuric acid		86	83	71	109	53
Imports:						
Elemental e		3,000	1,700	2,950	3,270	2,930
Sulfuric acid		1,690	413	690	872 r	933
Consumption, all forms[4]		12,900	9,460	11,300	11,700	11,000
Stocks, December 31, producer, recovered		208	231	166	175	132
Value:						
Shipments, free on board (f.o.b.) mine or plant:						
Recovered e, 2		2,250,000	14,000	587,000	1,310,000 e	1,040,000 e
Other		110,000	87,500	92,400	113,000	109,000
Total		2,360,000	101,000	679,000	1,430,000 r	1,150,000
Exports, elemental[5]		272,000	82,200	171,000	266,000	366,000
Imports, elemental		753,000	54,100	214,000	301,000	238,000
Price, elemental, f.o.b. mine or plant e	dollars per metric ton	264.04	1.73	70.16	159.88 r	123.54
World, production, all forms (including pyrites)		68,900 r	67,800 r	68,400 r	69,300 r	69,100

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]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)

	2011			2012		
		Shipments			Shipments	
State	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	297	298	55,400	272	274	37,600
California	999 [r]	997 [r]	142,000 [r]	1,040	1,040	154,000
Illinois	495	495	81,100	593	592	77,700
Louisiana	1,480	1,480	220,000	1,360	1,360	180,000
New Mexico	21	21	3,880	19	18	2,220
Ohio	136	137	27,000	130	131	20,400
Texas	2,900 [r]	2,890 [r]	470,000	3,190	3,180	377,000
Washington	127	127	17,000	165	165	17,900
Wyoming	647	649	121,000	591	589	32,100
Other[2]	1,120 [r]	1,110 [r]	175,000 [r]	1,050	1,110	144,000
Total	8,230	8,210	1,310,000	8,410	8,450	1,040,000

[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, Michigan, Minnesota, 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)

	2011		2012	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	66	61	132	136
Natural gas	13	13	13	13
Total	79	74	145	150
PAD 2:				
Petroleum and coke	1,020	1,030	1,080	1,080
Natural gas	21	21	18	18
Total	1,040	1,050	1,100	1,100
PAD 3:[2]				
Petroleum and coke	4,750 [r]	4,710 [r]	4,880	4,920
Natural gas	475 [r]	476 [r]	446	426
Total	5,220	5,190	5,320	5,350
PAD 4 and 5:				
Petroleum and coke	1,260	1,260	1,280	1,290
Natural gas	630	632	562	560
Total	1,890	1,890	1,840	1,850
Grand total	8,230	8,210	8,410	8,450
Of which:				
Petroleum and coke	7,090 [r]	7,060 [r]	7,370	7,430
Natural gas	1,140 [r]	1,140 [r]	1,040	1,020

[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	2011	2012
Copper[2]	679	545
Zinc, lead, and molybdenum[3]	41	41
Total:		
Quantity	720	586
Value	113,000	109,000

[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 BY TYPE[1]

(Thousand metric tons of sulfur content)

Type	2011	2012
Elemental sulfur:		
Shipments[2]	8,210	8,450
Exports	1,310	1,850
Imports[e]	3,270	2,930
Total	10,200	9,520
Byproduct sulfuric acid:		
Shipments	720	586
Exports[3]	109	53
Imports[3]	872	933
Total	1,480	1,470
Grand total	11,700	11,000

[e]Estimated.

[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] 2011	Elemental sulfur[2] 2012	Sulfuric acid (sulfur equivalent) 2011	Sulfuric acid (sulfur equivalent) 2012	Total 2011	Total 2012
102	Copper ores	--	--	410	420	410	420
1094	Uranium and vanadium ores	--	--	3	7	3	7
10	Other ores	--	--	77	77	77	77
26, 261	Pulp mills and paper products	W	W	168	168	168 r	168
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products[4]	W	W	118	107	118	107
281	Other inorganic chemicals	W	W	75	76	75	76
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	70	70	70	70
2823	Cellulosic fibers including rayon	--	--	--	--	--	--
284	Soaps and detergents	--	--	2	2	2	2
286	Industrial organic chemicals	--	--	43	37	43	37
2873	Nitrogenous fertilizers	--	--	163	163	163	163
2874	Phosphatic fertilizers	--	--	5,740	5,420	5,740	5,420
2879	Pesticides	--	--	5	8	5	8
287	Other agricultural chemicals	1,560	1,630	38	42	1,600	1,670
2892	Explosives	--	--	11	11	11	11
2899	Water-treating compounds	--	--	38	36	38	36
28	Other chemical products	--	--	74	69	74	69
29, 291	Petroleum refining and other petroleum and coal products	2,100	2,070	422	423	2,520	2,490
331	Steel pickling	--	--	11	11	11	11
33	Other primary metals	--	--	--	--	--	--
3691	Storage batteries (acid)	--	--	21	21	21	21
	Exported sulfuric acid	--	--	2	73	2	73
	Total identified	3,650	3,700	7,500	7,250	11,100	10,900
	Unidentified	282	372	149	165	431	537
	Grand total	3,940	4,070	7,650	7,410	11,600	11,500

[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	2011		2012	
	Quantity	Value	Quantity	Value
Brazil	594	106,000 r	749	129,000
Canada	71	16,100	33	12,200
Chile	44	7,190	235	35,200
China	62	26,500	162	41,700
Mexico	277	55,200	445	76,300
New Caledonia	83	16,300	--	--
Other	178	39,100 r	225	72,000
Total	1,310	266,000	1,850	366,000

rRevised. -- Zero.

[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	2011		2012	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	238,000	$21,000	114,000	$14,400
China	2,900	579	1,890	352
Dominican Republic	2,690	502	2,930	473
India	1,050	120	4	6
Israel	952	1,050	3,630	4,910
Jamaica	1,580	298	6,630	1,120
Kazakhstan	1,430	177	3,080	351
Latvia	7,470	1,310	--	--
Mexico	5,300	1,440	5,060	1,390
Morocco	1,010	115	--	--
Netherlands	2,000	260	325	48
Philippines	6,100	897	3,430	616
Singapore	9,730	1,720	1,650	1,610
St. Maarten	3,700	541	3,430	634
Trinidad and Tobago	6,360	4,220	4,730	2,780
United Kingdom	1,250	205	178	78
Venezuela	34,800	5,040	596	74
Other	6,100	2,020	8,820	4,240
Total	332,000	41,500	161,000	33,000

-- 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)

	2011		2012	
Country	Quantity	Value[2]	Quantity	Value[2]
Canada	2,700 [e]	188,000	2,440 [e]	163,000
Mexico	303	54,500	366	56,000
Venezuela	99	16,400	115	14,200
Other	168	42,700	6	4,600
Total	3,270 [e]	301,000	2,930 [e]	238,000

[e]Estimated.

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

[2]Declared customs valuation.

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

TABLE 10

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

	2011		2012	
Country	Quantity (metric tons)	Value[2, 3] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Australia	17,800	$2,480	--	--
Bulgaria	18,900	1,950	1	(4)
Canada	1,820,000	167,000	1,980,000	$155,000
China	15,600	976	1,020	928
Germany	93,500	10,700	100,000	7,740
Japan	94	81	18,500	982
Korea, Republic of	56,000	7,800	--	--
Mexico	434,000	30,400	470,000	33,700
Poland	77,700	10,600	111,000	9,370
Saudi Arabia	4,590	3,300	4,570	3,550
Spain	72,100	8,560	55,800	8,630
Sweden	18,100	1,940	52,800	2,980
Switzerland	15,100	2,250	29,100	2,120
Taiwan	2,980	1,380	1,010	1,100
Venezuela	13,400	9,330	14,900	10,600
Other	2,690	1,770	19,800	2,190
Total	2,670,000	261,000	2,860,000	239,000

-- 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.

[3]May include revisions to previously published data.

[4]Less than ½ unit.

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, 4]	2008	2009	2010	2011	2012
Australia, byproduct:[e]					
Metallurgy	880	870	800 [r]	800 [r]	800
Petroleum	60 [r]	60	60	60	60
Total	940 [r]	930	860 [r]	860 [r]	860
Brazil:					
Byproduct:					
Metallurgy	322	322	322	322 [e]	322 [e]
Petroleum	136	136	136	136	136 [e]
Frasch[e]	22	22	22	22	22
Total[e]	480	480	480	480	480
Canada, byproduct:					
Metallurgy	1,148	890	900 [e]	609	638 [p]
Natural gas, petroleum, oil sands	7,008	6,577	6,355	5,914	5,545 [p]
Total	8,156	7,467	7,260 [e]	6,523	6,183 [p]
Chile, byproduct, metallurgy	1,586	1,658	1,686	1,723	1,681
China:[e]					
Byproduct, all sources	3,350	4,000	4,100	3,300 [r]	3,300
Elemental	960	1,000	1,100	1,100	1,200
Pyrites	4,300	4,370	4,400	5,300 [r]	5,400
Total	8,610	9,370	9,600	9,700	9,900
Finland:[e]					
Byproduct:					
Metallurgy	331 [r]	274 [r]	275 [r]	280 [r]	280
Petroleum	117 [r]	127 [r]	125 [r]	133 [r]	130
Pyrites	226 [r]	154 [r]	150 [r]	338 [r]	330
Total	674 [r]	555 [r]	550 [r]	751 [r]	740
France, natural gas and petroleum:[e]	650 [r]	650 [r]	650 [r]	650 [r]	650
Germany, byproduct:					
Metallurgy	2,458	2,137	2,266	2,394	2,373
Natural gas and petroleum	1,709	1,623	1,447	1,514	1,445
Total	4,167	3,760	3,713	3,908	3,818
India:[e]					
Byproduct:					
Metallurgy (from fertilizer plants)	1,000 [r]	1,000 [r]	1,000 [r]	1,000 [r]	1,000
Natural gas and petroleum	1,400 [r]	1,400 [r]	1,400 [r]	1,400 [r]	1,400
Pyrites	32	31	31	30	30
Total	2,430 [r]	2,430 [r]	2,430 [r]	2,430 [r]	2,430
Iran, byproduct:[e]					
Metallurgy	70	70	80	80	90
Natural gas and petroleum	1,500	1,500	1,700	1,700	1,800
Total	1,570	1,570	1,780	1,780	1,890
Italy, byproduct:[e]					
Metallurgy	90	90	90	90	90
Petroleum	650	650	650	650	650
Total	740	740	740	740	740
Japan, byproduct:					
Metallurgy	1,300	1,350	1,400	1,450 [r]	1,500
Petroleum	2,034	1,864	1,892	1,755 [r]	1,747
Total	3,334	3,214	3,292	3,205 [r]	3,247
Kazakhstan, byproduct:[e]					
Metallurgy	300	300	300	300	300
Natural gas and petroleum	1,733 [5]	2,200	2,400	2,400	2,400
Total	2,030	2,500	2,700	2,700	2,700

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, 4]	2008	2009	2010	2011	2012
Korea, Republic of, byproduct:[e]					
Metallurgy	660	600	480	480	480
Petroleum	900 [r]	900 [r]	720 [r]	720 [r]	720
Total	1,560 [r]	1,500 [r]	1,200 [r]	1,200 [r]	1,200
Kuwait, byproduct, petroleum[e]	830	800	820	830	800
Mexico, byproduct:[e]					
Metallurgy	700	700	800 [r]	800 [r]	800
Natural gas and petroleum	1,041 [5]	1,114 [5]	992 [5]	959 [5]	1,010
Total	1,740	1,810	1,790 [r]	1,760 [r]	1,810
Netherlands, byproduct:[e]					
Metallurgy	115 [r]	115 [r]	115 [r]	115 [r]	115
Petroleum	400	400	400	400	400
Total	515 [r]	515 [r]	515 [r]	515 [r]	515
Poland:[6]					
Byproduct:					
Metallurgy	294	257	253 [r]	250 [r]	250 [e]
Natural gas[e]	21 [5]	25 [5]	25 [r]	25	25
Petroleum	201	190	225 [r]	200	200 [e]
Unspecified[e]	(7) [r]	1	1	1 [r]	1
Frasch	762	263	517	657 [r]	677
Total[e]	1,280	740	1,020 [r]	1,130 [r]	1,150
Qatar, byproduct, natural gas[e]	600 [r]	658 [5]	850 [r]	850 [r]	820
Russia:[e, 8]					
Byproduct:					
Metallurgy	100 [r]	100 [r]	100 [r]	200 [r]	300
Natural gas	6,100	6,000	6,000	6,000 [r]	6,000
Native	50	50	50	50	50
Pyrites	200	200	200	200	200
Total	6,450 [r]	6,350 [r]	6,350 [r]	6,450 [r]	6,550
Saudi Arabia, byproduct, all sources	3,163	3,214 [r]	3,200 [e]	4,579 [r]	4,092
South Africa:					
Byproduct:					
Metallurgy, copper, platinum, zinc plants	188	185	141 [r]	174 [r]	133 [e]
Petroleum	323	291	205 [r]	163 [r]	124 [e]
Pyrites, S content, from gold mines	61	60	30	-- [r]	--
Total	571	536	376 [r]	336 [r]	257 [e]
Spain, byproduct:[e]					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	500	536 [r]	539 [r]	539 [r]	540
Petroleum	136 [5]	136 [5]	136 [r]	136 [r]	140
Total	637	673 [r]	676 [r]	676 [r]	681
United Arab Emirates, byproduct, natural gas and petroleum	2,175	2,175 [r]	1,829 [r]	1,885 [r]	1,900 [e]
United States, byproduct:					
Metallurgy	753	749	791	720	586
Natural gas	1,300	1,220	1,170	1,140 [r]	1,040
Petroleum	7,240	6,970	7,150 [r]	7,090 [r]	7,370
Total	9,300	8,940	9,110 [r]	8,950	9,000
Uzbekistan, byproduct:[e]					
Metallurgy	170	170	170	170	170
Natural gas and petroleum	350	350	350	350	370
Total	520	520	520	520	540
Venezuela, byproduct, natural gas and petroleum[e]	710 [r, 5]	570 [r, 5]	800	800	800

See footnotes at end of table.

TABLE 11—Continued

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

(Thousand metric tons)

Country and source[3, 4]	2008	2009	2010	2011	2012
Other total	3,480 r	3,500 r	3,560 r	3,390 r	3,650
Of which:					
Byproduct:					
Metallurgy	829 r	969 r	1,060 r	909 r	990
Natural gas, petroleum, oil sands, undifferentiated	411 r	412 r	409 r	340 r	466
Petroleum	799 r	768 r	789 r	842 r	881
Of which:					
Native[9]	469 r	458 r	470 r	469 r	465
Pyrites	163 r	74 r	34 r	35 r	32
Unspecified	810 r	820 r	797 r	792 r	814
Grand total	68,900 r	67,800 r	68,400 r	69,300 r	69,100
Of which:					
Byproduct:					
Coal, lignite, gasification[e]	1	1	1	1	1
Metallurgy	13,800 r	13,300 r	13,600 r	13,400 r	13,400
Natural gas	8,030 r	7,900	8,040 r	8,010 r	7,880
Natural gas, petroleum, oil sands, undifferentiated	18,700	18,600 r	18,300 r	17,900	17,800
Petroleum	13,800 r	13,300 r	13,300	13,100 r	13,400
Frasch	784 r	285 r	539 r	680 r	699
Native[10]	1,480 r	1,510 r	1,620 r	1,620 r	1,720
Pyrites	4,980 r	4,890 r	4,850 r	5,900 r	5,990
Unspecified	7,320 r	8,030 r	8,100 r	8,670 r	8,210

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

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

[2]Includes data available through October 14, 2014.

[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]In addition to the countries listed, Bulgaria, Ecuador, and Vietnam produced native or byproduct sulfur [metallurgy, natural gas, and (or) petroleum], but available information is inadequate to formulate reliable estimates of output levels.

[5]Reported figure.

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

[7]Less than ½ unit.

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

[9]Includes "Belgium, elemental," "Egypt, elemental," and "Ukraine, elemental."

[10]Includes "Poland, Frasch."