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SULFUR [ADVANCE RELEASE]

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Sulfur

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In 2014, global consumption of sulfur increased by 2.2% compared with that in 2013, a result of a strong demand in nonfertilizer uses of sulfur and sulfuric acid. Consumption of sulfur for fertilizers increased slightly, owing to the small increase in demand for phosphate fertilizers worldwide. Overall, the global sulfur trade decreased slightly compared with that in 2013 owing to the worldwide decrease in sulfur imports from countries in North America, Africa, and East Asia (Prud'homme, 2015a, p. 48).

The United States ranked first in world sulfur production (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 31.0 million metric tons (Mt), which is equivalent to about 10.2 Mt of elemental sulfur, was produced worldwide in 2014, a 4% increase from that of 2013 (Prud'homme, 2014b, p. 37).

In 2014, domestic production of sulfur in all forms was 5% higher than that of 2013 and shipments of sulfur in all forms were 5% higher than those of 2013 (table 1). Elemental sulfur recovered at petroleum refineries was 6% higher than it was in 2013, and sulfur recovered from natural gas operations decreased slightly. Producers' stocks decreased by 12%, equivalent to less than 2% of shipments. Byproduct sulfuric acid production and shipments decreased by 5%. Apparent consumption of sulfur in all forms decreased by 3%. Imports of elemental sulfur and sulfuric acid combined decreased by 14% and exports increased by 12%. The average unit value of recovered sulfur in 2014 was 23% more than that of 2013, resulting in the value of total elemental sulfur shipments increasing by 19% compared with the value of shipments in 2013. The total value of byproduct sulfuric acid shipments decreased by about 9% (table 1).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; for 2014, global sulfur production was slightly higher than that of 2013 (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 slightly. In the few countries where pyrites (any of a number of metallic sulfides, especially of copper and tin) remain an important raw material for sulfuric acid production, sulfur production from pyrites was estimated to be about the same as in 2013.

Since 2005, more than 75% of the world's sulfur production as elemental sulfur and byproduct sulfuric acid has come 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 2.2% from that of 2013; typically, about 50% was used in fertilizer production and the remainder was used in myriad other industrial uses. World trade of elemental sulfur was estimated to have decreased slightly from the levels reported in 2013. Worldwide inventories of elemental sulfur declined as some of the increased demand was met by drawing down stocks in Canada and Kazakhstan (Prud'homme, 2015a, p. 48).

Legislation and Government Programs

On April 28, the U.S. Environmental Protection Agency (EPA) published the final rule of the Tier 3 Motor Vehicle Emission and Fuel Standards, which are designed to reduce air pollution from passenger cars and trucks. Starting January 1, 2017, under the Tier 3 fuel program, gasoline must contain no more than 10 parts per million (ppm) sulfur on an annual average basis. The implementation of these standards would result in reduction of pollutants such as ozone, particulate matter, and air toxins in an effort to maintain health-based National Ambient Air Quality Standards (U.S. Environmental Protection Agency, 2014). The amount of sulfur recovered from petroleum and natural gas refineries would increase with the implementation of these new standards, but the increase would be incremental because the previous standards set a limit of no more than 30 ppm sulfur in gasoline.

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. Of the 103 operations to which survey requests were sent, 99 responded; this represented 96% of the total production listed in table 1. In 2014, production was 5% higher and shipments were 5% higher than those of 2013. Higher sulfur prices resulted in the value of shipments of recovered material being 23% higher than that of 2013. For 2014, on average, U.S. petroleum refineries operated at 90.4% of capacity, a slight increase from that of 2013 (U.S. Energy Information Administration, 2015b).

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 40 companies at 103 plants in 27 States. 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, 36 plants produced more than 100,000 metric tons (t) of elemental sulfur in 2014; 18 produced between 50,000 and 100,000 t; 30 produced between 10,000 and 50,000 t; and 19 produced less than 10,000 t. By source, 89% 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., Valero Energy Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), Marathon Petroleum Corp., and Motiva Enterprises LLC. The 42 plants owned by these companies accounted for 57% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2014, 5 of the 20 largest oil refineries in the world, in terms of crude-processing capacity, were in the United States. In descending order of capacity, they were ExxonMobil's Baytown, TX, refinery; Marathon's Garyville, LA, refinery; ExxonMobil's Baton Rouge, LA, refinery; Marathon's Galveston Bay, TX, refinery; and Citgo Petroleum Corp.'s Lake Charles, LA, refinery (Oil & Gas Journal, 2014b). 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. The United States operated 20% of world refining capacity but had almost 41% of world sulfur recovery capacity at these refineries (Oil & Gas Journal, 2014a).

U.S. refining capacity rose slightly from 2010 through 2014 and rose by about 9% from 2000 through 2014, mostly from upgrades at existing refineries. In 2014, U.S. refinery capacity was 18.0 million barrels per day. Overall U.S. refinery capacity increased by about 63,000 barrels per day (bbl/d) in 2014. The new capacity was the result of the addition of two new refineries, one in North Dakota and another in Texas. Prior to these refineries, the last refinery was built in Wyoming in 2008. 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 (U.S. Energy Information Administration, 2015c).

During 2014, one improvement project was underway at a refinery in the United States but was not expected to be completed until 2016. All other projects to increase sulfur recovery were on hold (Sulphur, 2015b).

Byproduct Sulfuric Acid.**—**Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 6% of total domestic production of sulfur in all forms and totaled the equivalent of 587,000 t of elemental sulfur. Byproduct sulfuric acid production decreased by 5% compared with that of 2013 (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 93% of byproduct sulfuric acid output. The copper producers—ASARCO LLC, Rio Tinto Kennecott 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 3% lower than that of 2013 (table 5). Of the sulfur consumed, 69% was obtained from domestic sources as elemental sulfur (64%) and byproduct acid (5%) compared with 65% in 2013, 65% in 2012, 64% in 2011, and 67% in 2010. The remaining 31% was supplied by imports of recovered elemental sulfur (21%) and sulfuric acid (10%). 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 64% 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 82% 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 9%, and total reported sulfur consumption increased slightly. The reported decrease in sulfuric acid consumption can primarily be attributed to a 9% decrease in sulfur acid use in the production of phosphatic 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 7% to 7.01 Mt compared with 7.52 Mt in 2013, resulting mainly 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 8% to 3.4 Mt. In 2014, about 48% 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 increased by 4% from that of 2013. Consumption of sulfuric acid in copper ore leaching, which was the third-ranked end use, decreased by 12%.

Production data for sulfuric acid produced as a result of recycling spent and contaminated acid from petroleum alkylation and other processes in 2014 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 domestic producers decreased to 142,000 t, 12% less than those of 2013 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 5-day supply, which is about the same as in 2013. Final stocks in 2014 represented 3% 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

With a 2.2% increase in global consumption of sulfur during 2014, prices were higher than those of 2013. On the basis of value data reported to the USGS, the average unit value of shipments for all elemental sulfur was estimated to be $80.07 per metric ton, which was 17% more than that of 2013 but not as high as 2012 levels. The increased 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 $75 per ton. At the end of July, prices increased to $136 per ton. In early October, prices decreased to $129 per ton and remained at this price through 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 $135 to $140 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 2014.

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 2014, the ADNOC contract price averaged about $160 per ton, with the lowest price of $140 per ton in January and the highest price of $200 per ton in March (Fertilizer Week, 2014b).

Foreign Trade

Elemental sulfur exports from the United States were 2.0 Mt. The average unit value of exported elemental sulfur was $157 per ton, an 18% increase from $133 per ton in 2013 but not as high as $198 per ton in 2012 (table 7). The leading destination for this material was Brazil followed by, in descending order of quantity, Morocco, China, New Caledonia, and Mexico. 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 1.15 Mt, or 57% of total U.S. exports. Exports from the Gulf Coast were 818,000 t, or 41% of the U.S. total.

The United States continued to be a net importer of sulfur with 2.4 Mt of imports in 2014. Imports of elemental sulfur exceeded exports by about 370,000 t. Recovered elemental sulfur from Canada, Mexico, and Venezuela, delivered to U.S. terminals and consumers in the liquid phase, furnished almost 100% of U.S. sulfur import requirements. Total elemental sulfur imports in 2014 were 21% less than those of 2013, and lower prices for imported material resulted in the value being about 34% less than that of 2013. Imports from Canada, mostly by rail, were estimated to be 22% lower than those of 2013, waterborne shipments from Mexico were 29% lower, and waterborne imports from Venezuela were 8% lower. 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 trades in sulfuric acid. Sulfuric acid exports of 158,000 t were 5% lower than those of 2013 (table 8). Acid imports were about 20 times greater than exports at 3.2 Mt (tables 1, 10). Canada and Mexico were the sources of 83% 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 by ship, primarily from Asia and Europe. The tonnage of sulfuric acid imports was about 9% greater than that of 2013, 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 11% of the sulfur produced in all forms worldwide in 2014 (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 among the top producers whose primary sulfur source was pyrites. China accounted for 90% of world pyrites 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 84% of the total sulfur produced worldwide. In 2014, an estimated 30.6 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, Morocco and Tunisia, the United States, Brazil, and India (Prud'homme, 2015b, p. 35).

In 2014, sulfur consumption, which increased by 2.2%, exceeded global production, even with lower demand in the phosphate fertilizer sector. As a result, stocks in Canada and Kazakhstan were used to meet global needs (Prud'homme, 2015a, p. 48). Prices were lowest at the beginning of 2014 and increased through August. International prices for 2014 averaged about 29% higher than those in the United States. Sulfur imports decreased in most of the major sulfur-consuming countries. China, the world's leading importer in 2014, imported about 33% of the total.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was estimated to be 15% higher than that of 2013. Recovered elemental sulfur production and byproduct sulfuric acid production were slightly higher compared with those of 2013. Globally, production of sulfur from pyrites was estimated to have increased by 8%. 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 2014, sulfur production in Canada was 7% lower than it was in 2013. 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. The decline in sulfur production is attributed to the gradual depletion of sour natural gas.

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 and exporter of sulfur. Byproduct sulfuric acid production was expected to remain relatively stable.

Environment and Climate Change Canada published information on Canada's sulfur emissions in 2013, which indicated a slight decrease from those of 2012 and a 60% decrease from those of 1990. Sulfur emissions in Canada have declined as the result of improved sulfur recovery technology at nonferrous metal smelters but also as a result of reduced emissions from coal-fired, power-generating utilities and plant closures, as well as a reduction in emissions from the petroleum-refining sector. Further decreases in sulfur emissions were achieved through the implementation of low-sulfur fuel standards (Environment and Climate Change Canada, 2016).

At yearend 2013, sulfur inventory in western Canada was estimated to be 11 Mt. About 9.7 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 has been a major obstacle in the shipment of sulfur from oil sands production sites. Only about 1.3 Mt of the sulfur from central Alberta was easily marketable (Prud'homme, 2014a, p. 49).

In December, BP p.l.c. began operation at the Sunrise Phase 1 in situ oil sands project in Alberta, Canada, a 50–50 joint venture with Husky Energy Inc. The project, 60 kilometers northeast of Fort McMurray, was expected to be in production for approximately 50 years. The bitumen from the site was to be recovered using steam-assisted gravity drainage technology, a technology that does not require open pit mines or tailing ponds. The amount of sulfur expected to be produced from this site was not specified, but the site at full capacity was expected to process 200,000 bbl/d of bitumen (BP p.l.c., 2014).

China.—China was the second-leading global producer of sulfur in all forms. China was the world's leading producer of pyrites, with about 57% of its sulfur in all forms coming from that source. The country was the leading sulfur importer, with an estimated 10.5 Mt representing 33% of the global imports. Imports represented about 64% of elemental sulfur consumption in China, the bulk of which was used to manufacture sulfuric acid. Fertilizer production consumed about two-thirds of the sulfuric acid used in China (Prud'homme, 2015a, p. 51).

In December 2014, the Government of China released its 2015 export tariff rates for phosphate fertilizers, which loosened restrictions imposed on the fertilizer industry in China. The main change for the 2014 export tariff rates was that the taxation rate for the full year would be flat, with no high or low season adjustments. The year-round tariff rates for diammonium phosphate and monoammonium phosphate would be 100 renminbi (RMB) per ton (CRU Group, 2014).

India.—Indian Oil Corp. Ltd. was to begin commissioning its long-delayed $5.5 billion Paradip refinery in Odisha. The refinery, originally scheduled to be finished in 2012, would produce 6.0 million metric tons per year (Mt/yr) of diesel, 3.4 Mt/yr of gasoline, 1.45 Mt/yr of kerosene, 536,000 t/yr of liquefied petroleum gas, 124,000 t/yr of naptha, and 335,000 t/yr of sulfur. All products would be for sale on the domestic market. Commissioning of the refinery was to begin in the first quarter of 2015 (Sulphur, 2015a).

Iraq.—Devco USA, LLC, began the process of rebuilding the Mishraq State Sulfur Mine in Mosul. A total of $53 million worth of equipment was shipped to the mine in May 2014, with the facility expected to come online in the first quarter of 2015. The equipment was part of Devco's $78.5 million contract with the Iraqi Ministry of Industry to rebuild the facility. At full capacity, the mine would produce 500,000 t/yr of sulfur (Fertilizer Week, 2014a).

Mexico.—Petróleos Mexicanos S.A. de C.V. (Pemex) signed five contracts as part of a $2.8 billion project to upgrade five refineries in Ciudad Madero, Minatitlan, Salamanca, Salina Cruz, and Tula. The upgrades would reduce the sulfur content of the diesel produced by 97%; these refineries would produce ultra-low sulfur diesel that meets international standards. By 2015, 60% of the Pemex diesel would be ultra-low sulfur, and by 2017, the diesel produced would be 100% ultra-low sulfur (Sulphur, 2014a).

United Arab Emirates.—Abu Dhabi Gas Development Company Ltd.'s (Al Hosn Gas) $10 billion Shah sour gas project in Abu Dhabi was to begin in the second quarter of 2015. At full capacity, the Shah sour gas project was expected to produce 3 Mt/yr of sulfur. This major project would have an effect on the global sulfur prices as it would be the largest new source of sulfur coming online in 2015 (Sulphur, 2015c).

Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.5 Mt/yr. One project to increase sulfur recovery at a U.S. refinery is expected to be completed in 2016 (Sulphur, 2014a). Production from natural gas operations is expected to increase from that of 2014 as more natural gas is recovered from shale formations, horizontal drilling, and hydraulic fracturing. Use of natural gas in the industrial sector is expected to increase (U.S. Energy Information Administration, 2015a).

Worldwide recovered sulfur output is also expected to increase as a result of higher sulfur recovery in the oil and gas sector. Through 2015, worldwide production of sulfur was nearly balanced to meet demand. However, sulfur surpluses are expected in 2016, 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, Turkmenistan, China, and Qatar) (Prud'homme, 2015b).

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. U.S. gas production is expected to continue to increase from unconventional natural gas resources such as tight gas, shale gas, and coalbed methane (U.S. Energy Information Administration, 2015a, p. 78). 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 is 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 40% since 2000. China's smelter acid production has more than doubled in the past 5 years. China is forecasted to account for the majority of the increased smelter acid production followed by new environmentally mandated sulfur recovery at smelters in Namibia and Zambia. In addition, Indonesia's ban on exporting copper ores and concentrates is expected to lead to the construction of new smelters in that country (Sulphur, 2014b).

Frasch sulfur and pyrites production, however, are unlikely to have significant long-term increases. In 2014, Frasch sulfur production was about the same as that of 2013. 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 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 it 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; however, high costs and difficulty in the high pressure acid leach process for nickel may result in the use of a less expensive option. New copper production in Mexico and the United States and especially central Africa will lead to slightly more acid consumption (Sulphur, 2014b).

From year to year, however, the use of sulfur directly or in the production of 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 and Morocco, which are expected to account for one-half of the expansion, with other projects in Brazil, India, and Saudi Arabia (Heffer and Prud'homme, 2015). 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 would most likely consume huge quantities of sulfur in sulfur-extended asphalt and sulfur concretes. In many instances, these materials were determined 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 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 important.

In the near term, increased global production and continued demand will keep the sulfur market balanced, which 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)

		2010	2011	2012	2013	2014
United States:						
Quantity:						
Production:						
Recovered		8,320 [2]	8,230 [2]	8,410 [2]	8,590	9,040
Other		791	720	586	616	587
Total		9,110	8,950	9,000	9,210	9,630
Shipments:						
Recovered		8,380 [2]	8,210 [2]	8,450 [2]	8,590	9,080
Other		791	720	586	616	587
Total		9,170	8,930	9,030	9,200	9,670
Exports:						
Elemental		1,450 [3]	1,310 [3]	1,860 [r]	1,770 [r]	2,000
Sulfuric acid		71	108 [r]	53	54	52
Imports:						
Elemental[e]		2,950	3,270	2,930	2,990	2,370
Sulfuric acid		689 [r]	871 [r]	933	972	1,060
Consumption, all forms[4]		11,300	11,700	11,000	11,300 [r]	11,000
Stocks, December 31, producer, recovered		166	175	132	161	142
Value:						
Shipments, free on board (f.o.b.) mine or plant:						
Recovered[e]		587,000 [2]	1,310,000 [2]	1,040,000 [2]	590,000 [r]	727,000
Other		92,400	113,000	109,000	101,000	92,100
Total		679,000	1,430,000	1,150,000	691,000 [r]	819,000
Exports, elemental		173,000 [r, 5]	266,000 [5]	368,000 [r, 5]	235,000 [r]	314,000
Imports, elemental		214,000	301,000	238,000	202,000	134,000
Price, elemental, f.o.b. mine or plant[e]	dollars per metric ton	70.16	159.88	123.54	68.71 [r]	80.07
World, production, all forms (including pyrites)		69,600 [r]	70,600 [r]	70,000 [r]	68,300 [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 the 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)

State	2013 Production	2013 Shipments Quantity	2013 Shipments Value[e]	2014 Production	2014 Shipments Quantity	2014 Shipments Value[e]
Alabama	289	290	21,600	272	273	21,400
California	1,060	1,060	48,500	1,110	1,110	81,700
Illinois	606	607	37,600	596	596	49,300
Louisiana	1,450	1,450	97,100	1,490	1,490	126,000
New Mexico	16	17	748	18	18	818
Ohio	141	141	8,390	131	130	16,200
Texas	3,160	3,160	259,000	3,280	3,300	292,000
Washington	194	195	11,200	159	168	7,290
Wyoming	595 r	594	22,000 r	603	603	22,900
Other[2]	1,080	1,070	84,200	1,380	1,400	110,000
Total	8,590 r	8,590	590,000 r	9,040	9,080	727,000

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Montana, New Jersey, North Dakota, Oklahoma, Pennsylvania, Tennessee, Utah, Virginia, and Wisconsin.

TABLE 3
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES,
BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT[1]

(Thousand metric tons)

District and source	2013 Production	2013 Shipments	2014 Production	2014 Shipments
PAD 1:				
Petroleum and coke	183	184	220	219
Natural gas	13	13	13	13
Total	196	197	233	232
PAD 2:				
Petroleum and coke	1,070	1,070	1,290	1,280
Natural gas	13	13	8	8
Total	1,080	1,080	1,300	1,290
PAD 3:				
Petroleum and coke	4,910	4,900	5,110	5,130
Natural gas	434	434	414	416
Total	5,350	5,330	5,520	5,540
PAD 4 and PAD 5:				
Petroleum and coke	1,410	1,420	1,420	1,460
Natural gas	561	559	565	564
Total	1,970	1,980	1,990	2,020
Grand total	8,590	8,590	9,040	9,080
Of which:				
Petroleum and coke	7,570 r	7,570	8,040	8,080
Natural gas	1,020	1,020	1,000	1,000

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

TABLE 4

BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES[1]

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2013	2014
Copper[2]	574	545
Zinc, lead, and molybdenum	41	41
Total:		
Quantity	616	587
Value	101,000	92,100

[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.

TABLE 5

CONSUMPTION OF SULFUR IN THE UNITED STATES BY TYPE[1]

(Thousand metric tons of sulfur content)

Type	2013	2014
Elemental sulfur:		
Shipments	8,590	9,080
Exports	1,770 r	2,000
Imports[e]	2,990	2,370
Total	9,810 r	9,450
Byproduct sulfuric acid:		
Shipments	616	587
Exports[2]	54	52
Imports[2]	972	1,060
Total	1,530	1,600
Grand total	11,300 r	11,000

[e]Estimated. [r]Revised.

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

[2]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] code	End use	Elemental sulfur[2] 2013	Elemental sulfur[2] 2014	Sulfuric acid (sulfur equivalent) 2013	Sulfuric acid (sulfur equivalent) 2014	Total 2013	Total 2014
102	Copper ores	--	--	284	251	284	251
1094	Uranium and vanadium ores	--	--	5	4	5	4
10	Other ores	--	--	62	64	62	64
26, 261	Pulp mills and paper products	W	W	168	129	168	129
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products[4]	W	W	101	74	101	74
281	Other inorganic chemicals	W	W	76	58	76	58
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	70	6	70	6
2823	Cellulosic fibers including rayon	--	--	--	--	--	--
284	Soaps and detergents	--	--	2	2	2	2
286	Industrial organic chemicals	--	--	32	19	32	19
2873	Nitrogenous fertilizers	--	--	168	175	168	175
2874	Phosphatic fertilizers	--	--	5,270	4,810	5,270	4,810
2879	Pesticides	--	--	7	8	7	8
287	Other agricultural chemicals	2,030	1,970	47	51	2,080	2,020
2892	Explosives	--	--	9	7	9	7
2899	Water-treating compounds	--	--	36	34	36	34
28	Other chemical products	--	--	68	54	68	54
29, 291	Petroleum refining and other petroleum and coal products	1,970 r	2,120	1,270	1,260	3,250	3,380
331	Steel pickling	--	--	11	11	11	11
33	Other primary metals	--	--	--	--	--	--
3691	Storage batteries (acid)	--	--	21	21	21	21
	Exported sulfuric acid	--	--	73	77	73	77
	Total identified	4,000	4,090	7,780 r	7,120	11,800	11,200
	Unidentified	558 r	923	199	141	757 r	1,060
	Grand total	4,560 r	5,010	7,980 r	7,260	12,500 r	12,300

[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	2013		2014	
	Quantity	Value	Quantity	Value
Benin	--	--	28	3,740
Brazil	693	75,700	862	120,000
Canada	12	10,100	21	11,200
Chile	68	6,430	36	6,450
China	296	54,900	298	48,200
Colombia	17	1,050	<1	45
France	13	1,780	18	10,000
Indonesia	60	7,680	13	1,150
Israel	<1	6	32	4,620
Mexico	256	33,700 r	111	16,500
Morocco	227	18,200	332	42,100
Namibia	--	--	16	2,190
New Caledonia	57	3,940	212	32,200
Peru	15	1,480	<1	31
Other	59 r	20,400 r	21	15,700
Total	1,770 r	235,000 r	2,000	314,000

rRevised. -- Zero.

[1]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	2013		2014	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	108,000	$14,800	105,000	$10,100
China	3,500	482	526	87
Dominican Republic	29	29	3,620	205
Ecuador	3,110	550	25	16
Germany	1,140	189	6	19
Ireland	598	361	3,110	1,530
Israel	6,930	6,180	4,320	4,210
Jamaica	4,020	209	4,130	257
Kazakhstan	3,420	390	--	--
Mexico	7,830	2,090	6,290	1,790
Netherlands	8	15	2,010	202
Panama	2,010	342	2,120	180
Saudi Arabia	170	26	6,160	727
Singapore	1,010	947	456	95
Sint Maarten	5,040	406	4,030	289
Suriname	1,610	296	--	--
Taiwan	1,350	174	1,080	141
Thailand	535	106	38	93
Trinidad and Tobago	13,300	1,040	12,300	926
United Kingdom	139	79	573	97
Other	1,700 r	1,360 r	1,920	846
Total	165,000	30,100	158,000	21,800

rRevised. -- 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)

Country	2013		2014	
	Quantity	Value[2]	Quantity	Value[2]
Canada	2,420 e	135,000 r	1,880 e	83,600
Mexico	448	48,200	318	28,500
Venezuela	115	13,400	106	7,480
Other	11	5,750 r	64	14,100
Total	2,990 e	202,000	2,370 e	134,000

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared customs valuation.

Source: U.S. Census Bureau and 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]

Country	2013		2014	
	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Belgium	26,100	$1,190	26,900	$510
Brazil	--	--	597	402
Canada	2,050,000	145,000	2,040,000	126,000
Chile	10,000	541	--	--
China	1,000	928	828	802
Ecuador	825	610	1,700	1,260
Finland	12,400	502	26,400	716
Germany	89,500	4,800	78,700	3,380
Iraq	5,350	3,970	3,730	2,560
Libya	--	--	1,150	901
Mexico	555,000	34,800	658,000	35,800
Norway	7,880	71	--	--
Poland	53,700	1,370	78,800	2,580
Saudi Arabia	12,100	8,840	9,360	6,550
Spain	54,900	2,430	164,000	8,770
Sweden	65,100	3,920	146,000	6,720
Switzerland	25,600	618	20	12
Taiwan	1,130	1,180	3,520	2,810
Other	616 r	381 r	715	430
Total	2,970,000	211,000	3,240,000	200,000

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

TABLE 11

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

(Thousand metric tons)

Country and source[3]	2010	2011	2012	2013	2014
Australia, byproduct:[e]					
Metallurgy	800	800	800	810 r	810
Petroleum	60	60	60	90	90
Total	860	860	860	900 r	900
Belgium:[e]					
Elemental	225	225	225	225	225
Forms, unspecified	175	175	175	175	175
Total	400	400	400	400	400
Brazil, byproduct:					
Metallurgy	287 r	322	275 r	324 r	324 e
Petroleum	143	170	223	218 r	220 e
Total	430 r	492	497 r	542 r	544 e
Canada, byproduct:					
Metallurgy	900 e	609	638	699 r	649
Natural gas, petroleum, oil sands	6,355	5,914	5,545	5,666 r	5,265
Total	7,260 e	6,523	6,183	6,365 r	5,914
Chile, byproduct, metallurgy	1,686	1,723	1,681	1,700 e	1,700 e
China:[e]					
Elemental	1,100	1,100	1,200	930	1,000
Pyrites	4,400	5,300	5,400	4,580	5,000
Byproduct, all sources, unspecified	4,100	3,300	3,300	2,600	2,840
Total	9,600	9,700	9,900	8,110	8,840
Finland:[e]					
Byproduct:					
Metallurgy	275	280	280	280	280
Petroleum	125	133	130	130	130
Pyrites	150	338	330	330	330
Total	550	751	740	740	740
France, byproduct, natural gas and petroleum[e]	650	650	650	400 r	400
Germany, byproduct:					
Metallurgy	2,266	2,394	2,373	2,400 r, e	2,400 e
Natural gas and petroleum	1,447	1,514	1,445	1,400 r, e	1,400 e
Total	3,713	3,908	3,818	3,800 r, e	3,800 e
India:[e]					
Byproduct:					
Metallurgy (from fertilizer plants)	1,143 r, 4	1,000	1,209 r, 4	1,200 r	1,200
Natural gas and petroleum	1,600 r	1,600 r	1,600 r	1,600 r	1,500
Pyrites	30 r	30	30	30	30
Total	2,770 r	2,630 r	2,840 r	2,830 r	2,730
Iran, byproduct:[e]					
Metallurgy	80	75 r	90	95	90
Natural gas and petroleum	1,780	1,575 r	2,000 r	2,100 r	2,000
Total	1,860	1,650 r, 4	2,090 r	2,200 r	2,090
Italy, byproduct:[e]					
Metallurgy	90	90	90	90	90
Petroleum	650	650	650	650	650
Total	740	740	740	740	740
Japan, byproduct:					
Metallurgy	1,400	1,450	1,500	1,500	1,500
Petroleum	1,892	1,755	1,747	1,779 r	1,751
Total	3,292	3,205	3,247	3,279 r	3,251
Kazakhstan, byproduct:[e]					
Metallurgy	300	300	300	300 r	320
Natural gas and petroleum	2,400	2,400	2,151 r, 4	2,443 r, 4	2,455
Total	2,700	2,700	2,451 r, 4	2,743 r, 4	2,780
Korea, Republic of, byproduct, natural gas and petroleum[e]	1,200	1,200	1,350 r	1,400 r	1,400

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]	2010	2011	2012	2013	2014
Kuwait, byproduct, petroleum[e]	800 r	825 r	800	850 r	800
Mexico, byproduct:[e]					
Metallurgy	800	800	800	810 r	810
Natural gas and petroleum	670 4	636 4	592	620 r, 4	603
Total	1,470	1,440	1,390	1,430 r	1,410
Netherlands, byproduct:[e]					
Metallurgy	115	115	115	115	115
Petroleum	400	400	400	400	400
Total	515	515	515	515	515
Poland:[5]					
Byproduct:					
Metallurgy	253	250 r	250 r	250 r, e	250 e
Natural gas[e]	25	24	25	24 r	24
Petroleum (oil refineries and coking plants)	225	235	260	259 r, e	260 e
Sources, unspecified	1	1	(6)	1 r	1 e
Frasch	517	657	677	526	605 e
Total, byproduct and Frasch	1,020	1,170 r	1,210 r	1,060 r	1,140 e
Qatar, byproduct, natural gas[e]	850	850	820 r	820 r	850
Russia[e]					
Byproduct:					
Metallurgy	100	200	300	300	200
Natural gas	6,337 r, 4	6,488 r, 4	6,416 r, 4	5,977 r, 4	5,859
Petroleum	600	600	700	700	500
Native	78 r, 4	69 r, 4	69 r, 4	123 r, 4	120
Pyrites	200	200	200	200	180
Total	7,310 r	7,560 r	7,680 r	7,300 r	6,860
Saudi Arabia, all sources	3,200 e	4,579	4,092	3,900 r	4,400 e
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,829 4	1,885 4	1,900	2,000 r	2,400
United States, byproduct:					
Metallurgy	791	720	586	616	587
Natural gas	1,170	1,140	1,040	1,020	1,000
Petroleum	7,150	7,090	7,370	7,570 r	8,040
Total	9,110	8,950	9,000	9,210	9,630
Uzbekistan, byproduct:[e]					
Metallurgy	170	170	170	175 r	170
Natural gas and petroleum	350	350	370	380	370
Total	520	520	540	555 r	540
Venezuela, byproduct, natural gas and petroleum[e]	800	800	800	800	700
Other	3,850 r	3,750 r	3,580 r	3,490 r	3,480
Of which:					
Byproduct:					
Metallurgy	1,330 r	1,270 r	808 r	825 r	825
Natural gas, petroleum, oil sands, undifferentiated	344	247 r	444 r	299 r	275
Petroleum	1,170 r	1,180 r	1,180 r	1,100 r	1,100
All forms and sources, unspecified	668 r	749 r	833 r	960 r	990
Native[7]	267 r	267 r	290 r	274 r	259
Pyrites	64 r	35	32	28 r	25
Grand total	69,600 r	70,600 r	70,000 r	68,300 r	69,100
Of which:					
Byproduct:					
Metallurgy	13,300 r	13,100 r	12,400 r	12,600 r	12,500
Natural gas	8,380 r	8,500 r	8,300 r	7,840 r	7,730
Natural gas, petroleum, oil sands, undifferentiated	19,400 r	18,800 r	18,800 r	19,100 r	18,800
Petroleum	13,300 r	13,200 r	13,600 r	13,800 r	14,000
All forms and sources, unspecified	8,140 r	8,800 r	8,400 r	7,630 r	8,410

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]	2010	2011	2012	2013	2014
Grand total—Continued					
Of which—Continued:					
Frasch	517	657	677	526	605
Native[8]	1,670 r	1,660 r	1,780 r	1,550 r	1,600
Pyrites	4,840 r	5,900	5,990	5,170 r	5,570

[e]Estimated. [r]Revised.

[1]Grand totals, 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 August 10, 2016.

[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 synthetic 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, pyrites-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 of the crude product from which the sulfur is extracted.

[4]Reported figure.

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

[6]Less than ½ unit.

[7]Includes "Egypt, elemental," and "Ukraine, elemental."

[8]Includes "Belgium, elemental," "China, elemental," "Egypt, elemental," and "Ukraine, elemental."