



2016 Minerals Yearbook

SULFUR [ADVANCE RELEASE]

SULFUR

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The United States was the world's leading producer of sulfur in 2016 (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.

In 2016, domestic production and shipments of sulfur in all forms were slightly higher than those of 2015 (table 1). Elemental sulfur recovered at petroleum refineries was 5% higher than it was in 2015, and sulfur recovered from natural gas operations was 20% lower than that of 2015 (table 3). Producers' stocks, equivalent to 2% of the shipments, increased by 4%. Byproduct sulfuric acid production and shipments increased by 4%. Apparent consumption of sulfur in all forms decreased by 5%. Imports of elemental sulfur and sulfuric acid combined decreased by 16%, and exports increased by 11%. The average unit value of recovered sulfur in 2016 was 57% less than that of 2015, resulting in the value of total elemental sulfur shipments decreasing by 56% compared with the value of shipments in 2015. The total value of byproduct sulfuric acid shipments decreased by about 14% (table 1).

Through its major derivative, sulfuric acid, sulfur ranks as one of the most important elements used as an industrial raw material and is of prime importance to every sector of the world's fertilizer and manufacturing industries. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indexes of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other inorganic chemical; 32.4 million metric tons (Mt), which is equivalent to about 10.6 Mt of elemental sulfur, was produced in 2016 (Meena Chauhan, Integer Research Ltd., written commun., April 4, 2018).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; for 2016, global sulfur production, in all forms, was about the same as that of 2015 (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 was essentially unchanged. In the few countries where pyrites remain an important raw material for sulfuric acid production, sulfur production from pyrites was estimated to be about the same as that of 2015.

Since 2005, more than 75% of the world's sulfur production has been byproduct from natural gas and petroleum processing and contained in byproduct sulfuric acid from nonferrous metal smelting. 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.

In 2016, global consumption of sulfur was estimated to have increased by 5% compared with that in 2015. Typically, about 50% is used in fertilizer production and the remainder is used in myriad other industrial uses. Increased consumption was a result of sustained demand in sulfur-based fertilizer production and industrial uses. World trade of elemental sulfur was estimated to have increased by 5% from the levels reported in 2015. Two-thirds of the traded sulfur was consumed by five countries (China, Jordan, Morocco, Tunisia, and the United States). Worldwide elemental sulfur was in surplus but the sulfur market remained balanced (Prud'homme, 2016b, p. 39).

Legislation and Government Programs

In October 2016, the International Maritime Organization (IMO) proceeded with its plan to reduce maximum allowable levels of sulfur and other pollutants in marine fuels used on the open seas from 3.5% to 0.5% by weight starting in 2020. The IMO's decision on marine fuel regulations limiting sulfur content followed the implementation of Emissions Control Area requirements in coastal waters and specific sea-lanes in North America and Europe. The requirement for North America and Europe reduces the allowable sulfur content in shipping fuel from 1% to 0.1% by weight starting in July 2015. The IMO sulfur limits require refiners to increase the supply of lower sulfur blendstocks to the bunker fuel market and develop new strategies to deal with the high-sulfur residual oil that can no longer be blended into bunker fuel (U.S. Energy Information Administration, 2016).

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 100 operations to which survey requests were sent, 99 responded; this represented 99% of the total production listed in table 1. In 2016, production and shipments were slightly higher than those of 2015. Lower sulfur prices resulted in the value of shipments of recovered material being 56% lower than that of 2015. For 2016, on average, U.S. petroleum refineries operated at 90% of capacity, a slight decrease from that of 2015 (U.S. Energy Information Administration, 2017b).

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 100 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 that responded to the canvass, 34 plants produced more than 100,000 metric tons (t) of elemental sulfur in 2015; 18 produced between 50,000 and 100,000 t; 31 produced between 10,000 and 50,000 t; and 16 produced less than 10,000 t. By source, 91% 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., Motiva Enterprises LLC, BP p.l.c., and Chevron Corp. The 45 plants owned by these companies accounted for 68% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2016, 5 of the 20 largest oil refineries in the world, in terms of crude-petroleum-processing capacity, were in the United States. In descending order of capacity, they were Motiva's Port Arthur, TX, refinery; ExxonMobil's Baytown, TX, refinery; Marathon's Garyville, LA, refinery; ExxonMobil's Baton Rouge, LA, refinery; and Marathon's Galveston Bay, TX, refinery (Oil & Gas Journal, 2016a). The capacity to process large quantities of crude petroleum 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 petroleum that were refined at the specific refineries. Major refineries that process low-sulfur crude petroleum 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, 2016c).

U.S. refining capacity rose by 6% from 2012 through 2016 and rose by about 11% from 2000 through 2016, mostly from upgrades at existing refineries. In 2016, U.S. refinery capacity was 18.4 million barrels per day, 1.9% higher than that of 2015. Overall U.S. refinery capacity increased by about 340,000 barrels per day (bbl/d) in 2016. Although sulfur capacity expansion was not specifically mentioned, any such expansions would likely include increased sulfur recovery facilities, probably proportionally higher than the increases in throughput capacity. In 2016, a new 42,500-bbl/d refinery was built in Corpus Christi, TX, but was not operational until January 2017 (U.S. Energy Information Administration, 2017b, c).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 6.9% of total domestic production of sulfur in all forms and totaled the equivalent of 673,000 t of elemental sulfur. Byproduct sulfuric acid production increased by 4% compared with that of 2015 (tables 1, 4). Three sulfuric 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 88% 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 5% less than that of 2015 (table 5). Of the sulfur consumed, 73% was obtained from domestic sources as elemental sulfur (67%) and byproduct acid (6%) compared with 69% in 2015, 69% in 2014, 65% in 2013, and 65% in 2012. The remaining 27% was supplied by imports of recovered elemental sulfur (17%) 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 69% 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 89% 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) increased by 20%, and total reported sulfur consumption increased by 8%. The reported increase in sulfuric acid consumption can primarily be attributed to a 26% increase in sulfuric 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 (table 6).

Agriculture was the leading sulfur-consuming industry; 2016 consumption in this end use was about 7.3 Mt, which was about 6% more than that of 2015. On the basis of export data reported by the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased by 9% to 3.4 Mt. In 2016, 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 decreased by 3% from that of 2015.

Consumption of sulfuric acid in copper ore leaching, which was the third-ranked end use, increased by 8%.

Two types of companies recycle spent and contaminated acid from petroleum alkylation—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, but insufficient data were available to make reasonable estimates.

In the second half of 2016, The Mosaic Co. began operating its sulfur melter at the New Wales, FL, facility. The new 1.0-million-metric-ton-per-year (Mt/yr) sulfur melter allowed Mosaic to transport solid sulfur by oceangoing vessels and melt it onsite for consumption. This ended the company's reliance on molten sulfur, a change that may reduce United States consumption of sulfur imported from Canada (Fertilizer International, 2016).

Stocks

Yearend inventories held by domestic producers of recovered elemental sulfur increased to 144,000 t, 4% higher than those of 2015 (table 1). On the basis of apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 5-day supply, which is about the same as that in 2015. Final stocks in 2016 represented about 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

The unit value of sulfur produced in the United States was lower in 2016 than in 2015 as a result of decreased demand for phosphate fertilizers and increased inventories. On the basis of value data reported to the USGS, the average unit value of shipments for all elemental sulfur was estimated to be \$37.88 per metric ton, which was 57% less than that of 2015. Several plants reported values of less than \$0 per metric ton, reflecting a cost to remove sulfur from the plant. The decreased unit value reported by producers correlated with the trends in prices recorded in trade publications, which indicated a 42% decrease in prices.

Contract prices for elemental sulfur at terminals in Tampa, FL, which were reported weekly in Green Markets, began the year at \$110 per ton. By mid-July, prices decreased to \$65 per ton, and in mid-October, prices increased to about \$70 per ton and remained at this price through yearend.

Prices vary greatly on a regional basis. Tampa, FL, prices usually were the highest reported in the United States because of the large demand for sulfur in the central Florida area; however, U.S. west coast average prices were higher in 2016. At yearend, U.S. west coast prices ranged from \$80 per ton to \$85 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 2016.

Even though prices vary by location, provider, and type, the Abu Dhabi National Oil Co. (ADNOC) price is recognized as an indicator of world sulfur price trends. In 2016, the ADNOC contract price averaged about \$84 per ton, with the lowest price of \$70 per ton in August and the highest price of \$122 per ton in January (Fertilizer Week, 2016).

Foreign Trade

Elemental sulfur exports from the United States were 2.0 Mt. The average unit value of exported elemental sulfur was \$104 per ton, a 32% decrease from \$154 per ton in 2015 (tables 1, 7). The leading destination for this material was Brazil followed by, in descending order of quantity, Mexico, Morocco, New Caledonia, and China. Export facilities on the Gulf Coast that began shipping in 2006 have become significant outlets for exported sulfur. Exports from the Gulf Coast were 1.16 Mt, or 57% of the U.S. total. Exports from the west coast were 823,000 t, or 40% of total U.S. exports.

In 2016, the United States imported 1.8 Mt of sulfur. Recovered elemental sulfur from Canada delivered to United States terminals and consumers in the liquid phase furnished 82% of United States sulfur import requirements. Total elemental sulfur imports in 2016 were 19% less than those of 2015, and lower prices for imported material resulted in the value being 41% lower than that of 2015. Imports from Canada, mostly by rail, were estimated to be 20% lower than those of 2015 (table 9).

In addition to elemental sulfur, the United States trades in sulfuric acid. Sulfuric acid exports of 177,000 t were about the same as those of 2015 (table 8). Acid imports were about 18 times greater than exports at about 3.2 Mt (tables 1, 10). Canada and Mexico were the sources of 85% of sulfuric acid imported into the United States, most of which was probably byproduct acid from nonferrous metal 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% less than that of 2015, and the value of imported sulfuric acid decreased by about 33%.

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 only 10% of the sulfur in all forms produced worldwide in 2016 (table 11).

Poland, with 630,000 t, was the only country that produced more than 300,000 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 87% of the total sulfur produced worldwide.

In 2016, an estimated 34.6 Mt of elemental sulfur was traded globally. The leading exporters were, in descending order by tonnage, United Arab Emirates, Canada, Saudi Arabia, and Russia. The leading importer was China, by far, followed by Morocco, the United States, Tunisia, and Jordan (Prud'homme, 2016b, p. 39).

Sulfur consumption was estimated to have increased globally by 5%. The sulfur market had a global surplus in 2016 but the market remained balanced. Prices were highest at the beginning of 2016 and decreased through September. International prices for 2016 averaged about 9% higher than those in the United States. Sulfur imports increased in most of the major sulfur-consuming countries with China importing about 33% of the total (Prud'homme, 2016b, p. 39).

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was estimated to be slightly higher than that of 2015. Recovered elemental sulfur production and byproduct sulfuric acid production were slightly higher compared with those of 2015. Globally, production of sulfur from pyrites was estimated to have remained the same. Pyrites is 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 one of the leading sulfur and sulfuric acid exporters. In 2016, sulfur production in Canada was 7% lower than it was in 2015. 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 was attributed to the gradual depletion of sour natural gas deposits.

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 production decreases. Exploration for conventional natural gas came to a halt in 2012. Sulfur production from oil sands operations was expected to overtake that from 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 export of sulfur. Byproduct sulfuric acid production was expected to remain relatively stable.

Environment and Climate Change Canada (2017) published information on Canada's sulfur emissions in 2015, which indicated a 13% decrease from those of 2014 and a 66% 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, electric-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.

In May 2016, wildfires around Fort McMurray in northern Alberta forced evacuations and shut down production at most of the major oil sands facilities in the region. At these operations, daily production can be as high as 1.1 million bbl/d, but during May, daily production averaged about 800,000 bbl/d. During June, production was about 400,000 bbl/d below normal. Sulfur production in the Fort McMurray area, which would have declined proportionally to that of petroleum during the fire emergency, usually totals about 1.8 Mt/yr (Sulphur, 2016b).

China.—China was the second leading global producer of sulfur in all forms and the 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 11 Mt representing about one-third of global imports (Prud'homme, 2016b, p. 39). Imports represented about 67% of elemental sulfur consumption in China, the bulk of which was used to manufacture sulfuric acid. Fertilizer production consumed about 60% of the sulfuric acid used in China, of which 84% was used in the production of phosphoric-acid-based fertilizers (Prud'homme, 2016a).

In December 2016, the Government of China released its 2017 export tariff rates for phosphate fertilizers. The tariff rates for diammonium phosphate and monoammonium phosphate were reduced to zero from 100 Renminbi per ton in 2016 (CRU Group, 2016).

Saudi Arabia.—Saudi Aramco planned to build the Fadhili gas plant 30 kilometers west of Jubail. The plant would have a processing capacity of 2.5 billion cubic feet per day and would process gas from both onshore and offshore fields. The gas plant would produce 1.5 billion cubic feet per day of gas and 4,000 metric tons per day of sulfur. The plant was expected to cost \$13.3 billion. Scheduled to be completed by yearend 2019, the plant would supply natural gas to Saudi Arabia and reduce the country's reliance on oil as fuel for power generation (Oil & Gas Journal, 2016b).

Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.6 Mt/yr. Production from natural gas operations is expected to increase from that of 2016 as more natural gas is recovered from shale formations, horizontal drilling, and hydraulic fracturing. Use of natural gas in the industrial and electric power sectors is expected to increase. Improvements in drilling technology have kept production in pace with demand for domestic consumption and export (U.S. Energy Information Administration, 2017a).

Worldwide recovered sulfur output is also expected to increase as a result of higher sulfur recovery in the oil and gas sector. Emerging supply would mostly come from China, Saudi Arabia, Turkmenistan, and the United Arab Emirates. Through 2015, worldwide production of sulfur was nearly equal to consumption. However, in 2016 sulfur was in surplus and sulfur production is expected to continue to be greater than demand thus increasing the surplus (Prud'homme, 2016b).

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 petroleum, 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. natural gas production is expected to continue to increase from shale gas, tight gas, and offshore because of abundant U.S. resources and technology improvements (U.S. Energy Information Administration, 2017a, p. 58). 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 35% since 2000. China's smelter acid production has nearly doubled in the past 10 years; however, the rate of increase has begun to slow. China, Cuba, Morocco, and Namibia are the main locations for new smelter capacity (Sulphur, 2016a).

Frasch sulfur and pyrites production, however, are unlikely to have significant long-term increases. In 2016, Frasch sulfur production was about the same as that of 2015. 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, is 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. Phosphate processing, mainly for agricultural uses, continues to be the dominant use of sulfuric acid (about 60%). Phosphate fertilizer is expected to remain a leading end use as the global demand for fertilizer remains strong. Ore leaching (about 10%) likely will be the largest area of sulfur consumption growth. Copper and nickel leaching are major consumers of sulfuric acid; however, high costs and technical difficulties in the high-pressure acid leach process for nickel may result in the use of a less expensive option. In addition, other industrial applications such as caprolactam and titanium dioxide production are expanding. Industrial demand for sulfur is increasing, especially in China and Russia (Sulphur, 2016c).

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. Phosphate fertilizer production expansions are expected at facilities in China, Morocco, and Saudi Arabia (Prud'homme, 2017, p. 32). 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. Interest in use of sulfur concrete may occur in regions where there is a looming sulfur surplus.

Increased global sulfur production from natural gas (in particular sour natural gas) and crude petroleum refineries has exceeded demand beginning a worldwide sulfur surplus. However, the international sulfur trade is expected to be strong, driven by demand for sulfuric acid in industrial sectors (particularly new copper and nickel leaching operations) and a steady increase in consumption in fertilizers.

References Cited

- CRU Group, 2016, China's—Urea, DAP/MAP export taxes abolished from Jan 1: CRU Group, CRU Views Fertilizers, December 23.
- Environment and Climate Change Canada, 2017, Sulphur oxide emissions: Gatineau, Quebec, Canada, Environment and Climate Change Canada, August 9. (Accessed February 26, 2018, at <https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=402A9845->.)
- Fertilizer International, 2016, Mosaic's game-changing sulphur melter: Fertilizer International, v. 472, May–June, p. 24–29.
- Fertilizer Week, 2016, Fertilizer Week historical prices December 22, 2016: Fertilizer Week, December 22. (Accessed February 12, 2018, via <https://www.crugroup.com/knowledge-and-insights/spotlights/fertilizer-week-real-time-news-and-weekly-pricing/>.)
- Oil & Gas Journal, 2016a, 2016 worldwide refining survey: Oil & Gas Journal, December 5, 2 p. (Accessed February 1, 2018, via <http://www.ogj.com/ogj-survey-downloads.html>.)
- Oil & Gas Journal, 2016b, Aramco lets contract for Fadhili gas project: Oil & Gas Journal, July 20. (Accessed February 1, 2018, at <https://www.ogj.com/articles/2016/07/aramco-lets-contracts-for-fadhili-gas-project.html>.)
- Oil & Gas Journal, 2016c, Worldwide refineries—Capacities as of January 1, 2017: Oil & Gas Journal, December 5, 2 p. (Accessed February 1, 2018, via <http://www.ogj.com/ogj-survey-downloads.html>.)
- Prud'homme, Michel, 2016a, Fertilizers and raw materials global supply 2016–2020: Paris, France, International Fertilizer Industry Association Annual Conference, Moscow, Russia, May 30–June 1, 81 p. (Accessed February 1, 2018, via <https://www.fertilizer.org>.)
- Prud'homme, Michel, 2016b, Global fertilizer supply and trade 2016–2017: Paris, France, International Fertilizer Association Strategic Forum, Dubai, United Arab Emirates, November 26–28, 45 p. (Accessed February 1, 2018, via <https://www.fertilizer.org>.)
- Prud'homme, Michel, 2017, Fertilizers and raw materials global supply 2017–2021: Paris, France, International Fertilizer Association Annual Conference, Marrakech, Morocco, May 22–24, 61 p. (Accessed February 1, 2018, via <https://www.fertilizer.org>.)
- Shelton, J.E., 1980, Sulfur and pyrites, in *Metals and minerals*: U.S. Bureau of Mines Minerals Yearbook 1978–79, v. I, p. 877–897.
- Sulphur, 2016a, Acid test ahead for smelters: Sulphur, no. 366, September–October, p. 4.
- Sulphur, 2016b, Canada—Fires shut down oil sands production: Sulphur, no. 365, July–August, p. 10.

- Sulphur, 2016c, The global market for sulphur: Sulphur, no. 367, November–December, p. 18–20.
- U.S. Energy Information Administration, 2016, Tighter marine fuel sulfur limits will spark changes by both refiners and vessel operators: U.S. Energy Information Administration, November 30. (Accessed March 19, 2018, at <https://www.eia.gov/todayinenergy/detail.php?id=28952>.)
- U.S. Energy Information Administration, 2017a, Annual energy outlook 2017 with projections to 2050: U.S. Energy Information Administration, January 5, 127 p. (Accessed March 20, 2018, at [http://www.eia.gov/outlooks/aeo/pdf/0383\(2017\).pdf](http://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf).)
- U.S. Energy Information Administration, 2017b, Refinery utilization and capacity: U.S. Energy Information Administration, December. (Accessed January 10, 2018, at http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.)
- U.S. Energy Information Administration, 2017c, U.S. refinery capacity at the start of 2017 is 1.6% above its year-earlier level: U.S. Energy Information Administration, July 6. (Accessed February 26, 2018, at https://www.eia.gov/petroleum/weekly/archive/2017/170706/includes/analysis_print.php.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
- Sulfur. Ch. in *Mineral Commodity Summaries*, annual.
- Sulfur. Ch. in *United States Mineral Resources*, Professional Paper 820, 1973.
- Sulfur. *Mineral Industry Surveys*, monthly.

Other

- Chemical and Engineering News, weekly.
- Chemical Engineering, weekly.
- Fertilizer International, bimonthly.
- Fertilizer Week, weekly.
- Green Markets, weekly.
- ICIS PentaSul North America Sulphur Review, monthly.
- Industrial Minerals, monthly.
- Oil & Gas Journal, weekly.
- Sulfur. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.
- Sulphur, bimonthly.

TABLE 1
SALIENT SULFUR STATISTICS¹

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

	2012	2013	2014	2015	2016
United States:					
Quantity:					
Production:					
Recovered	8,410 ²	8,590	9,050	8,890	9,070
Other	586	616	587	646	673
Total	9,000	9,210	9,630	9,540	9,740
Shipments:					
Recovered	8,450 ²	8,590	9,080	8,910	9,080
Other	586	616	587	646	673
Total	9,040 ^r	9,200	9,670	9,560	9,750
Exports:					
Elemental	1,860	1,770	2,020 ^r	1,840 ^r	2,050
Sulfuric acid	53	54	53 ^r	58 ^r	58
Imports:					
Elemental ^c	2,930	2,990	2,370	2,240	1,820
Sulfuric acid	933	972	1,000	1,160	1,050
Consumption, all forms ³	11,000	11,300	11,000	11,100	10,500
Stocks, producer, recovered, December 31	132	160	141	138	144
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Recovered ^c	1,040,000 ²	590,000	734,000 ^r	781,000	344,000
Other	109,000	101,000	92,100	75,500 ^r	64,800
Total	1,150,000	691,000	826,000 ^r	857,000 ^r	409,000
Exports, elemental	368,000 ⁴	235,000	315,000	284,000 ^r	213,000
Imports, elemental	238,000	202,000	134,000	136,000	79,800
Price, elemental, f.o.b. mine or plant ^c	dollars per metric ton				
	123.54	68.71	80.07	87.62	37.88
World, production, all forms (including pyrites)	71,400 ^r	69,800 ^r	71,300 ^r	73,800 ^r	73,500

^cEstimated. ^rRevised.

¹Table includes data available through June 27, 2018. Data are rounded to no more than three significant digits except prices; may not add to totals shown.

²Includes the U.S. Virgin Islands.

³Calculated as shipments minus exports plus imports.

⁴Includes value of exports from the U.S. Virgin Islands to foreign countries.

TABLE 2
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE¹

(Thousand metric tons and thousand dollars)

State	2015			2016		
	Production	Shipments		Production	Shipments	
		Quantity	Value ^c		Quantity	Value ^c
Alabama	270	270	23,300	157	157	4,620
California	1,010	1,010	87,500	1,070	1,070	36,500
Illinois	546	546	46,700	614	613	17,700
Louisiana	1,530	1,530	136,000	1,650	1,650	66,500
New Mexico	11	11	508	3	3	33
Ohio	125	125	16,000	131	132	2,420
Texas	3,250	3,250	338,000	3,310	3,300	171,000
Washington	150	151 ^r	6,920	161	161	3,500
Wyoming	599	601	22,500	582	582	13,100
Other ²	1,400	1,420	103,000	1,400	1,420	28,800
Total	8,890	8,910	781,000	9,070	9,080	344,000

^cEstimated. ^rRevised.

¹Table includes data available through June 27, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes 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) DISTRICT¹

(Thousand metric tons)

District and source	2015		2016	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	193	194	186	185
Natural gas	13	13	13	13
Total	207	207	199	198
PAD 2:				
Petroleum and coke	1,320	1,320	1,420	1,420
Natural gas	13	13	10	10
Total	1,330	1,330	1,430	1,430
PAD 3:				
Petroleum and coke	5,080	5,090	5,290	5,280
Natural gas	395	394 ^r	224	228
Total	5,480	5,480	5,510	5,500
PAD 4 and PAD 5:				
Petroleum and coke	1,320	1,330	1,390	1,420
Natural gas	561	563	534	535
Total	1,880	1,890	1,930	1,950
Grand total	8,890	8,910	9,070	9,080
Of which:				
Petroleum and coke	7,910	7,930	8,290	8,290
Natural gas	982	983 ^r	781	786

^rRevised.

¹Table includes data available through June 27, 2018. 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 STATES¹

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2015	2016
Quantity:		
Copper ²	553	590
Zinc, lead, and molybdenum	93	83
Total	646	673
Value	75,500	64,800

¹Table includes data available through June 27, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Excludes acid made from pyrites concentrates.

TABLE 5
CONSUMPTION OF SULFUR IN THE UNITED STATES BY TYPE¹

(Thousand metric tons of sulfur content)

Type	2015	2016
Elemental sulfur:		
Shipments	8,910	9,080
Exports	1,840 ^r	2,050
Imports ^c	2,240	1,820
Total	9,310	8,850
Byproduct sulfuric acid:		
Shipments	646	673
Exports ²	58 ^r	58
Imports ²	1,160	1,050
Total	1,740 ^r	1,670
Grand total	11,100	10,500

^cEstimated. ^rRevised.

¹Table includes data available through June 27, 2018. 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.

²May include sulfuric acid other than byproduct.

TABLE 6
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE¹

(Thousand metric tons of sulfur content)

SIC ² code	End use	Elemental sulfur ³		Sulfuric acid (sulfur equivalent)		Total	
		2015	2016	2015	2016	2015	2016
102	Copper ores	--	--	278	301	278	301
1094	Uranium and vanadium ores	--	--	1	5	1	5
10	Other ores	--	--	70	63	70	63
26, 261	Pulp mills and paper products	-- ^r	W	124	119	124	127
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products ⁴	W	W	128 ^r	79	150 ^r	101
281	Other inorganic chemicals	W	W	62 ^r	62	98 ^r	65
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	6	6	6	6
284	Soaps and detergents	--	--	5	5	5	5
286	Industrial organic chemicals	--	--	27	22	27	22
2873	Nitrogenous fertilizers	--	--	198	305	198	305
2874	Phosphatic fertilizers	--	--	4,610	5,820	4,610	5,820
2879	Pesticides	--	--	8	7	8	7
287	Other agricultural chemicals	2,000 ^r	1,100	34	29	2,030 ^r	1,130
2892	Explosives	--	--	8	8	8	8
2899	Water-treating compounds	--	--	32	34	32	34
28	Other chemical products	--	--	54	56	54	56
29, 291	Petroleum refining and other petroleum and coal products	2,250	2,210	428	387	2,680	2,590
331	Steel pickling	--	--	11	11	11	11
3691	Storage batteries (acid)	--	--	22	21	22	21
	Exported sulfuric acid	--	--	72	72	72	72
	Total identified	4,250 ^r	3,300	6,180	7,420	10,500 ^r	10,800
	Unidentified	1,030 ^r	2,400	140 ^r	133	1,170 ^r	2,530
	Grand total	5,280 ^r	5,700	6,320	7,550	11,700 ^r	13,300

^rRevised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.

¹Table includes data available through June 27, 2018. Data are rounded to no more than three significant digits; may not add to totals

²Standard Industrial Classification.

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

⁴No elemental sulfur was used in inorganic pigments, paints, and allied products.

TABLE 7
U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY OR LOCALITY¹

(Thousand metric tons and thousand dollars)

Country or locality	2015		2016	
	Quantity	Value	Quantity	Value
Brazil	759 ^r	105,000 ^r	719	60,900
Canada	70	10,900	13	9,260
China	253	42,200	167	30,700
Mexico	204	30,900	448	39,000
Morocco	217	31,300	382	32,600
New Caledonia	137	17,500	202	16,100
Other	205 ^r	46,900	119	24,800
Total	1,850	284,000 ^r	2,050	213,000

^rRevised.

¹Table includes data available through June 27, 2018. 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% H₂SO₄), BY COUNTRY OR LOCALITY¹

Country or locality	2015		2016	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	120,000 ^r	\$11,600 ^r	111,000	\$12,400
Curacao	1,100	71	--	--
Dominican Republic	2,970	298	22	28
Ireland	13,300	6,350	7,320	9,650
Israel	3,370	3,150	5,360	2,590
Jamaica	2,310	163	2,220	174
Korea, Republic of	996	162	5,310	159
Malaysia	1,110	156	27	11
Mexico	6,680	1,230	5,440	1,210
Panama	3,150	312	--	--
Saudi Arabia	1,940	4,250	16	13
Suriname	494	115	16,100	758
Taiwan	3,460	495	1,130	175
Trinidad and Tobago	4,370	417	338	142
Venezuela	8,100	651	20,200	1,760
Other	3,770 ^r	1,310 ^r	2,610	959
Total	177,000 ^r	30,700	177,000	30,000

^rRevised. -- Zero.

¹Table includes data available through June 27, 2018. 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 OR LOCALITY¹

(Thousand metric tons and thousand dollars)

Country or locality	2015		2016	
	Quantity	Value ²	Quantity	Value ²
Canada	1,860 ^e	87,100	1,480 ^e	45,700
Mexico	190	16,500	73	1,830
Venezuela	20	425	9	808
Other	169	31,600	253	31,400
Total	2,240 ^e	136,000	1,820 ^e	79,800

^eEstimated.

¹Table includes data available through June 27, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Declared customs valuation.

Sources: 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% H₂SO₄), BY COUNTRY OR LOCALITY¹

Country or locality	2015		2016	
	Quantity (metric tons)	Value ² (thousands)	Quantity (metric tons)	Value ² (thousands)
Belgium	18,100	\$656	13	\$2
Brazil	5,110	2,060	1,270	228
Canada	2,070,000	124,000	2,100,000	91,800
Chile	10,000	673	--	--
China	1,360	1,230	2	2
Finland	189,000	8,350	109,000	3,760
Germany	107,000	4,050	145,000	3,920
Iraq	1,970	648	3,790	790
Mexico	768,000	41,000	640,000	26,100
Norway	13,700	784	--	--
Peru	36,300	760	--	--
Poland	51,300	2,830	3	6
Saudi Arabia	10,400	3,610	9,510	2,560
Spain	155,000	10,200	151,000	5,090
Sweden	96,900	3,880	29,900	1,040
Taiwan	3,120	2,490	3,170	2,620
Other	1,700 ^r	887 ^r	23,600	1,220
Total	3,540,000	208,000	3,220,000	139,000

^rRevised. -- Zero.

¹Table includes data available through June 27, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

TABLE 11
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE^{1,2}

(Thousand metric tons, sulfur content)

Country or locality	2012	2013	2014	2015	2016
Australia, byproduct: ^c					
Metallurgy	800	810	810	810	810
Petroleum	60	90	90	90	90
Total	860	900	900	900	900
Belgium, byproduct, all forms and sources, unspecified	382 ^r	397 ^r	400 ^e	400 ^e	400 ^e
Brazil, byproduct:					
Metallurgy	275	324	287	290 ^e	290 ^e
Petroleum	223	218	240	240 ^e	240 ^e
Total	498 ^r	542	527	530	530
Canada, byproduct:					
Metallurgy	665 ^r	677 ^r	590 ^r	558 ^r	664
Natural gas and petroleum, including oil sands	5,594 ^r	5,624 ^r	5,252 ^r	5,187 ^r	4,653
Total	6,260 ^r	6,300 ^r	5,840 ^r	5,750 ^r	5,320
Chile, byproduct, metallurgy	1,681	1,771 ^r	1,849 ^r	1,800 ^{r,e}	1,800 ^e
China:					
Byproduct:					
Metallurgy	1,200	930	1,000 ^e	1,000 ^e	1,000 ^e
Petroleum	3,300	2,600	2,840	2,800 ^e	2,800 ^e
Pyrites	5,400	4,580	5,000 ^e	5,000 ^e	5,000 ^e
Total	9,900	8,110	8,840	8,800 ^e	8,800 ^e
Finland:					
Byproduct:					
Metallurgy	330 ^r	316 ^r	336 ^r	336 ^r	340
Petroleum	122 ^r	130	130 ^e	130 ^e	130 ^e
Pyrites	375 ^r	347 ^r	353 ^r	350 ^r	350
Total	827 ^r	793 ^r	819 ^r	816 ^r	820
France, byproduct:					
Natural gas and petroleum	650	400	400 ^e	400 ^e	400 ^e
All forms and sources, unspecified ^c	78	78	78	78	78
Total	728 ^r	478 ^r	478 ^r	478 ^r	478
Germany, byproduct:					
Metallurgy	2,373	2,400 ^e	2,400 ^e	2,400 ^e	2,400 ^e
Natural gas and petroleum	1,445	1,400 ^e	1,400 ^e	1,400 ^e	1,400 ^e
Total	3,820 ^r	3,800	3,800	3,800	3,800
India, byproduct:					
Metallurgy ^e	1,209	1,200	1,200	1,200	1,200
Natural gas and petroleum ^c	2,057 ^r	1,987 ^r	1,901 ^r	1,928 ^r	1,930
Total	3,270 ^r	3,190 ^r	3,100 ^r	3,130 ^r	3,130
Iran, byproduct, natural gas and petroleum ^c	2,000	2,100	2,000 ^r	2,200 ^r	2,200
Italy, byproduct: ^c					
Metallurgy	58 ^r	40 ^r	40 ^r	40 ^r	40
Petroleum	540 ^r	510 ^r	510 ^r	510 ^r	510
Total	598 ^r	550 ^r	550 ^r	550 ^r	550
Japan, byproduct:					
Metallurgy	1,756 ^r	1,686 ^r	1,752 ^r	1,688 ^r	1,690 ^e
Petroleum	1,747	1,779	1,751	1,733 ^r	1,730 ^e
Total	3,503 ^r	3,465 ^r	3,503 ^r	3,421 ^r	3,420
Kazakhstan, byproduct:					
Metallurgy ^e	588 ^r	605 ^r	604 ^r	604 ^r	604
Natural gas and petroleum	2,151	2,443	2,465 ^r	2,515 ^r	2,520 ^e
Total	2,740 ^r	3,050 ^r	3,070 ^r	3,120 ^r	3,120
Korea, Republic of, byproduct:					
Metallurgy	1,078	1,078	1,078	1,078	1,078 ^e
Natural gas and petroleum ^c	1,350	1,350 ^r	1,350 ^r	1,350 ^r	1,350
Total	2,430	2,430	2,430	2,430	2,430
Kuwait, byproduct, petroleum ^c	844 ^r	850	850 ^r	850	850
Mexico, byproduct, all forms and sources, unspecified	1,012 ^r	1,030 ^r	993 ^r	859 ^r	673

See footnotes at end of table.

TABLE 11—Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE^{1,2}

(Thousand metric tons, sulfur content)

Country or locality	2012	2013	2014	2015	2016
Netherlands, byproduct: ^e					
Metallurgy	118 ^r	121 ^r	120 ^r	120 ^r	120
Petroleum	450 ^r	430 ^r	410 ^r	410 ^r	410
Total	568 ^r	551 ^r	530 ^r	530 ^r	530
Poland: ³					
Byproduct:					
Metallurgy	267 ^r	260 ^r	260 ^{r,e}	280 ^{r,e}	280 ^e
Natural gas	25	24	24	24	24 ^e
Petroleum	260	269 ^r	269 ^{r,e}	269 ^{r,e}	270 ^e
All forms and sources, unspecified	(4)	1	1	1	1 ^e
Frasch	677	526	605	627 ^r	630 ^e
Total	1,230 ^r	1,080 ^r	1,160 ^{r,e}	1,200 ^r	1,210
Qatar, byproduct, natural gas	1,844 ^r	1,979 ^r	1,900 ^{r,e}	1,900 ^{r,e}	1,900 ^e
Russia:					
Byproduct:					
Metallurgy ^e	300	300	200	200	200
Natural gas	6,416	5,977	5,859	5,961 ^r	5,960 ^e
Petroleum ^e	700	700	500	500	500
Native	69	123	119 ^{r,e}	120 ^e	120 ^e
Pyrites ^e	200	200	180	180	180
Total	7,690 ^r	7,300	6,860 ^r	6,960 ^r	6,960
Saudi Arabia, byproduct, all forms and sources, unspecified	4,092	3,900	4,400	4,900 ^e	4,900 ^e
Turkmenistan, byproduct, all forms and sources, unspecified	240	400	506	600	600 ^e
United Arab Emirates, byproduct, natural gas and petroleum ^c	2,200 ^r	2,510 ^r	3,300 ^r	5,300 ^r	5,300
United States, byproduct:					
Metallurgy	586	616	587	646	673
Natural gas	1,040	1,020	1,000	982	781
Petroleum	7,370	7,570	8,040	7,910	8,290
Total	9,000	9,210	9,630	9,540	9,740
Uzbekistan, byproduct: ^c					
Metallurgy	131 ^r	131 ^r	131 ^r	131 ^r	130
Natural gas and petroleum	360 ^r	330 ^r	340 ^r	340 ^r	340
Total	491 ^r	461 ^r	471 ^r	471 ^r	470
Venezuela, byproduct, natural gas and petroleum ^c	800	800	700	700	700
Other:					
Byproduct:					
Metallurgy	371 ^r	380 ^r	362 ^r	305 ^r	310
Natural gas and petroleum	429 ^r	450 ^r	472 ^r	450 ^r	450
Petroleum	527 ^r	444 ^r	542 ^r	539 ^r	536
All forms and sources, unspecified	366 ^r	320 ^r	320 ^r	335 ^r	446
Frasch and native	214 ^r	199 ^r	181 ^r	198 ^r	198
Pyrites	52 ^r	45 ^r	40 ^r	40 ^r	40
Total	1,960 ^r	1,840 ^r	1,920 ^r	1,870 ^r	1,980
Grand total	71,400 ^r	69,800 ^r	71,300 ^r	73,800 ^r	73,500
Of which:					
Byproduct:					
Metallurgy	13,800 ^r	13,600 ^r	13,600 ^r	13,500 ^r	13,600
Natural gas	9,320 ^r	9,000 ^r	8,780 ^r	8,870 ^r	8,670
Natural gas and petroleum, including oil sands	17,000 ^r	17,400 ^r	17,700 ^r	19,800 ^r	19,300
Petroleum	18,200 ^r	17,600 ^r	18,100 ^r	17,900 ^r	18,300
All forms and sources, unspecified	6,170 ^r	6,130 ^r	6,700 ^r	7,170 ^r	7,100
Frasch and native	960	848	905	945	948
Pyrites	6,030 ^r	5,170	5,570	5,570	5,570

See footnotes at end of table.

TABLE 11—Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE^{1,2}

(Thousand metric tons, sulfur content)

⁶Estimated. ⁷Revised.

¹Table includes data available through November 16, 2017. All data are reported unless otherwise noted. Grand totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²The 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.

³Government 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.

⁴Less than ½ unit.