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SULFUR

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The United States lead the world in sulfur production in 2015 (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 2015, domestic production and shipments of sulfur in all forms were slightly lower than those of 2014 (table 1). Elemental sulfur recovered at petroleum refineries was slightly higher than it was in 2014, and sulfur recovered from natural gas operations was about the same as that of 2014. Producers' stocks, equivalent to 2% of the shipments, decreased slightly. Byproduct sulfuric acid production and shipments increased by 10%. Apparent consumption of sulfur in all forms increased slightly. Imports of elemental sulfur and sulfuric acid combined increased slightly and exports decreased by 8%. The average unit value of recovered sulfur in 2015 was 9% more than that of 2014, resulting in the value of total elemental sulfur shipments increasing by 7% compared with the value of shipments in 2014. The total value of byproduct sulfuric acid shipments decreased by about 18% (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; an estimated 27 million metric tons (Mt), which is equivalent to about 9 Mt of elemental sulfur, was produced in 2015 (Integer Research Ltd., written commun., May 4, 2016).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; for 2015, global sulfur production was slightly higher than that of 2014 (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 decreased slightly. In the few countries where pyrites (common minerals composed of iron and sulfur compounds, such as marcasite, pyrite, and pyrrhotite) remain an important raw material for sulfuric acid production, sulfur production from pyrites was estimated to be about the same as in 2014.

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.

In 2015, global consumption of sulfur was estimated to have increased by 3.5% compared with that in 2014. 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; however, ore leaching declined (Prud'homme, 2015, p. 36). World trade of elemental sulfur was estimated to have increased by 5% from the levels reported in 2014 owing to expanded sulfur import demand from China, Morocco, and Southeast and West Asia (Prud'homme, 2016, p. 51). Worldwide inventories of elemental sulfur declined as the large sulfur stocks in Kazakhstan were depleted and availability of sulfur stocks from Canada decreased. In the past decade, stocks from Canada and Kazakhstan provided additional sulfur supply during the deficit in sulfur production (Prud'homme, 2015, p. 33).

Legislation and Government Programs

On January 1, 2015, the International Maritime Organisation's global sulfur standard of maritime fuels was implemented in northern Europe and along the North American coastline Emission Control Areas (ECA) reducing the allowable sulfur content in shipping fuel from 1% to 0.1% (1,000 parts per million). All vessels that operate in the ECA are required to be in compliance with the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI ECA fuel oil sulfur standard. This standard applies to large marine diesel engines propelling large ships and ocean-going vessels (Category 3 Engines) operating within the ECAs (U.S. Environmental Protection Agency, 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 101 operations to which survey requests were sent, 100 responded; this represented 99% of the total production listed in table 1. In 2015, production and shipments were slightly lower than those of 2014. Higher sulfur prices resulted in the value of shipments of recovered material being 7% higher than that of 2014. For 2015, on average, U.S. petroleum refineries operated at 91% of capacity, a slight increase from that of 2014 (U.S. Energy Information Administration, 2016b).

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 101 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, 33 plants produced more than 100,000 metric tons (t) of elemental sulfur in 2015; 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, Valero Energy Corp., Exxon Mobil 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 56% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2015, 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, 2014). 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 21% of world refining capacity but had almost 41% of world sulfur recovery capacity at these refineries (Oil & Gas Journal, 2015).

U.S. refining capacity rose by 3% from 2011 through 2015 and rose by about 11% from 2000 through 2015, mostly from upgrades at existing refineries. In 2015, U.S. refinery capacity was 18.3 million barrels per day, 1.9% higher than that of 2014. Overall U.S. refinery capacity increased by about 350,000 barrels per day (bbl/d) in 2015. The increased capacity included the addition of two new refineries, which began operating in 2015, one in Corpus Christi, TX, (46,250 bbl/d) and the other in Houston, TX, (25,000 bbl/d). 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 (U.S. Energy Information Administration, 2016c). During 2015, one improvement project was underway at a refinery in the United States and was expected to be completed in 2016 (Sulphur, 2016).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 6.8% of total domestic production of sulfur in all forms and totaled the equivalent of 646,000 t of elemental sulfur. Byproduct sulfuric acid production increased by 10% compared with that of 2014 (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 86% 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 slightly higher than that of 2014 (table 5). Of the sulfur consumed, 69% was obtained from domestic sources as elemental sulfur (64%) and byproduct acid (5%) compared with 69% in 2014, 65% in 2013, 65% in 2012, and 64% in 2011. The remaining 31% was supplied by imports of recovered elemental sulfur (20%) and sulfuric acid (11%). 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 58% 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 81% 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 slightly, and total reported sulfur consumption increased by 9%. The reported decrease in sulfuric acid consumption can primarily be attributed to a 4% 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 (table 6).

Agriculture was the leading sulfur-consuming industry; 2015 consumption in this end use was about 7.0 Mt, which was about the same as that of 2014. Based on export data reported by the

U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased by 9% to 3.1 Mt. In 2015, about 45% of the domestic phosphate fertilizer production was exported.

The second-ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported that the consumption of sulfur in that end use increased by 6% from that of 2014. Consumption of sulfuric acid in copper ore leaching, which was the third-ranked end use, increased by 11%.

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.

Stocks

Yearend inventories held by recovered elemental sulfur domestic producers decreased to 138,000 t, slightly lower than those of 2014 (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 2014. Final stocks in 2015 represented about 2% of the quantity held in inventories at the end of 1976, when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1980, p. 877). When the United States mined large quantities of sulfur, as in 1976, mining companies had the capacity to store large quantities. When mining ceased in 2000, storage capacity declined significantly. Since that time, stocks have been relatively low because recovered sulfur producers have minimal storage capacity.

Prices

With a 3.5% increase in global consumption of sulfur during 2015, prices were higher than those of 2014. On the basis of value data reported to the USGS, the average unit value of shipments for all elemental sulfur was estimated to be $87.62 per metric ton, which was 9% more than that of 2014 but not as high as 2011 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 $129 per ton. At the beginning of February, prices increased to $147 per ton. In mid-October, prices decreased to $110 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; however, west coast average prices were higher in 2015. At yearend, U.S. west coast prices ranged from $110 per ton to $115 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 2015.

Even though prices vary by location, provider, and type, the Abu Dhabi National Oil Co.'s (ADNOC's) price is recognized as an indicator of world sulfur price trends. In 2015, the ADNOC contract price averaged about $145 per ton, with the lowest price of $115 per ton in October and the highest price of $180 per ton in February (Fertilizer Week, 2015).

Foreign Trade

Elemental sulfur exports from the United States were 1.8 Mt. The average unit value of exported elemental sulfur was $152 per ton, a 3% decrease from $157 per ton in 2014 but not as high as $198 per ton in 2011 (tables 1, 7). The leading destination for this material was Brazil followed by, in descending order of quantity, China, Morocco, Mexico, New Caledonia, and Canada. Export facilities on the Gulf Coast that began shipping in 2006 have become significant outlets for exported sulfur. Exports from the Gulf Coast were 1.01 Mt, or 55% of the U.S. total. Exports from the west coast were 751,000 t, or 41% of total U.S. exports.

The United States continued to be a net importer of sulfur with 2.2 Mt of imports in 2015. Imports of elemental sulfur exceeded exports by about 390,000 t. Recovered elemental sulfur from Canada, Mexico, and Venezuela, delivered to United States terminals and consumers in the liquid phase, furnished more than 90% of United States sulfur import requirements. Total elemental sulfur imports in 2015 were 5% less than those of 2014, but higher prices for imported material resulted in the value being about the same as that of 2014. Imports from Canada, mostly by rail, were estimated to be slightly lower than those of 2014, waterborne shipments from Mexico were 40% lower, and waterborne imports from Venezuela were 81% lower. Canada was the source of an estimated 83% of elemental sulfur imports, and Mexico supplied 8% (table 9).

In addition to elemental sulfur, the United States trades in sulfuric acid. Sulfuric acid exports of 172,000 t were 7% higher than those of 2014 (table 8). Acid imports were about 20 times greater than exports at 3.5 Mt (tables 1, 10). Canada and Mexico were the sources of 80% 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 15% greater than that of 2014, and the value of imported sulfuric acid increased by about 9%.

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 11% of the sulfur in all forms produced worldwide in 2015 (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 2015, an estimated 33.0 Mt of elemental sulfur was traded globally. The leading exporters were, in decreasing order of tonnage, Canada, Saudi Arabia, Russia, Abu Dhabi, Kazakhstan, 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, 2015, p. 35).

With sulfur consumption increasing by 3.5%, the sulfur market was nearly balanced between production and consumption. In 2015, Kazakhstan sulfur stocks were depleted and the availability of sulfur stocks from Canada was reduced as a result of weak economics; both sources had been used to meet global needs during the past decade (Prud'homme, 2016, p. 51). Prices were highest at the beginning of 2015 and decreased through October. International prices for 2015 averaged about 10% higher than those in the United States. Sulfur imports increased in most of the major sulfur-consuming countries. China imported about 33% of the total.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was estimated to be slightly lower than that of 2014. Recovered elemental sulfur production and byproduct sulfuric acid production were slightly higher compared with those of 2014. Globally, production of sulfur from pyrites was estimated to have remained the same. 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 2015, sulfur production in Canada was 2% lower than it was in 2014. 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 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 export of sulfur. Byproduct sulfuric acid production was expected to remain relatively stable.

Environment and Climate Change Canada (2016) published information on Canada's sulfur emissions in 2014, which indicated a 5% decrease from those of 2013 and a 63% 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.

At yearend 2015, sulfur inventories in western Canada were 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, 2014, p. 49).

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 11.9 Mt representing 36% of global imports. 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, 2016, p. 54).

In December 2015, the Government of China released its 2016 export tariff rates for phosphate fertilizers. The tariff rates for diammonium phosphate and monoammonium phosphate were unchanged and would remain at 100 Renminbi (RMB) per ton (CRU Group, 2015).

Egypt.—The Middle East Oil Refinery was expanding capacity from 100,000 bbl/d to 150,000 bbl/d, a 50% increase. The cost for the upgrade was $1.4 billion, and the expanded refinery was expected to produce 100,000 t/yr of sulfur (Sulphur, 2015a).

Kuwait.—The Kuwait National Petroleum Co. awarded $11.5 billion in contracts for the construction of a new Al-Zour oil refinery. The projected capacity for the refinery was 615,000 bbl/d. Recovered sulfur from Al-Zour was expected to be 500,000 t/yr when the plant was fully operational. The refinery was expected to be commissioned by late 2018 or early 2019 (Sulphur, 2015b).

Venezuela.—Expansion of the El Palito refinery, owned by the Venezuelan state oil firm Petróleos de Venezuela, S.A., was expected to be completed in 2016. Refinery capacity was designed to increase from 135,000 bbl/d to 280,000 bbl/d. In addition, sulfur recovery expansion would increase capacity to 250 metric tons per day of sulfur (Sulphur, 2015e).

Outlook

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.6 million metric tons per year. Production from natural gas operations is expected to increase from that of 2015 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, both for domestic consumption and export (U.S. Energy Information Administration, 2016a).

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 the near future, 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 China, Turkmenistan, Qatar, and the United Arab Emirates) (Prud'homme, 2015).

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. 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, 2016a, p. 21). 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; however, the rate of increase has begun to slow as a result of a decrease in China's economic growth. Africa, China, Russia, and Southeast Asia are the main locations for new smelter capacity (Sulphur, 2015c).

Frasch sulfur and pyrites production, however, are unlikely to have significant long-term increases. In 2015, Frasch sulfur production was about the same as that of 2014. 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. Phosphate processing, mainly for agricultural uses, continues to be the dominate use of sulfuric acid. Phosphate fertilizer is expected to remain a leading end use as the global demand for fertilizer remains strong. 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, the United States, and especially central Africa would lead to slightly more acid consumption from this sector (Sulphur, 2015d).

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 (Heffer and Prud'homme, 2016). 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.

Increased global production from refineries and in particular sour gas projects indicates that a worldwide sulfur surplus may occur in the near future. 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 demand for fertilizers.

References Cited

CRU Group, 2015, China's 2016 urea, DAP/MAP export taxes unchanged: CRU Group, CRU Views Fertilizers, December 11.

Environment and Climate Change Canada, 2016, Sulphur oxide emissions: Gatineau, Quebec, Canada, Environment and Climate Change Canada, May 25. (Accessed February 2, 2017, at https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=402A9845-.)

Fertilizer Week, 2015, Fertilizer Week historical prices December 23, 2015: Fertilizer Week, December 23.

Heffer, Patrick, and Prud'homme, Michel, 2016, Fertilizer outlook 2016–2020, *in* IFA Annual Conference: International Fertilizer Industry Association, 84th, Moscow, Russia, May 30–June 1, Proceedings, 5 p.

Oil & Gas Journal, 2014, Asia-Pacific refining primed for capacity growth: Oil & Gas Journal, v. 112.12, December 1, p. 34–45.

Oil & Gas Journal, 2015, 2015 worldwide refining survey—Capacities as of January 1, 2016: Oil & Gas Journal, December 7, 2 p. (Accessed January 19, 2017, via http://www.ogj.com/ogj-survey-downloads.html.)

Prud'homme, Michel, 2014, Fertilizers and raw materials global supply 2014–2018, *in* IFA Annual Conference: International Fertilizer Industry Association, 82d, Sydney, New South Wales, Australia, May 26–28, Proceedings, 61 p.

Prud'homme, Michel, 2015, Global fertilizer supply and trade 2015–2016: Paris, France, International Fertilizer Industry Association, Strategic Forum, November 18–19, 58 p.

Prud'homme, Michel, 2016, Fertilizers and raw materials global supply 2016–2020, *in* IFA Annual Conference: International Fertilizer Industry Association, 84th, Moscow, Russia, May 30–June 1, Proceedings, 68 p.

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, 2015a, Egypt—Midor refinery expansion: Sulphur, no. 358, May–June, p. 11.

Sulphur, 2015b, Kuwait—Refinery contracts awarded: Sulphur, no. 360, September–October, p. 12.

Sulphur, 2015c, Prospects for new smelter acid production: Sulphur, no. 359, July–August, p. 24–27.

Sulphur, 2015d, The global market for sulphur: Sulphur, no. 357, March–April, p. 26–28.

Sulphur, 2015e, Venezuela—Sulphur output at El Palito to increase: Sulphur, no. 357, March–April, p. 12.

Sulphur, 2016, Sulphur recovery project listing: Sulphur, no. 363, March–April, p. 26–30.

U.S. Energy Information Administration, 2016a, Annual energy outlook 2016 with projections to 2040: U.S. Energy Information Administration, DOE/EIA-0383(2016), August, 256 p. (Accessed February 2, 2017, at http://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf.)

U.S. Energy Information Administration, 2016b, Refinery utilization and capacity: U.S. Energy Information Administration, December. (Accessed January 19, 2017, at http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.)

U.S. Energy Information Administration, 2016c, U.S. refinery capacity rises 1.9%: U.S. Energy Information Administration, June 29. (Accessed January 23, 2017, at http://www.eia.gov/petroleum/weekly/archive/2016/160629/includes/analysis_print.cfm.)

U.S. Environmental Protection Agency, 2016, Guidance documents for marine fuel: U.S. Environmental Protection Agency, September 28. (Accessed February 16, 2016, at https://www.epa.gov/fuels-registration-reporting-and-compliance-help/guidance-documents-marine-fuel.)

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 STATISTICS[1]

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

		2011	2012	2013	2014	2015
United States:						
Quantity:						
Production:						
Recovered		8,230 [2]	8,410 [2]	8,590	9,050 [r]	8,890
Other		720	586	616	587	646
Total		8,950	9,000	9,210	9,630	9,540
Shipments:						
Recovered		8,210 [2]	8,450 [2]	8,590	9,080	8,910
Other		720	586	616	587	646
Total		8,930	9,030	9,200	9,670	9,560
Exports:						
Elemental		1,310 [3]	1,860	1,770	2,010 [r]	1,850
Sulfuric acid		108	53	54	52	56
Imports:						
Elemental[e]		3,270	2,930	2,990	2,370	2,240
Sulfuric acid		871	933	972	1,000 [r]	1,160
Consumption, all forms[4]		11,700	11,000	11,300	11,000	11,100
Stocks, December 31, producer, recovered		176 [r]	132	160 [r]	141 [r]	138
Value:						
Shipments, free on board (f.o.b.) mine or plant:						
Recovered[e]		1,310,000 [2]	1,040,000 [2]	590,000	727,000	781,000
Other		113,000	109,000	101,000	92,100	36,700
Total		1,430,000	1,150,000	691,000	819,000	818,000
Exports, elemental		266,000 [5]	368,000 [5]	235,000	315,000 [r]	281,000
Imports, elemental		301,000	238,000	202,000	134,000	136,000
Price, elemental, f.o.b. mine or plant[e]	dollars per metric ton	159.88	123.54	68.71	80.07	87.62
World, production, all forms (including pyrites)		69,900 [r]	69,800 [r]	68,000 [r]	69,100	69,500

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits except prices; may not add to totals shown.
[2]Includes 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, sulfur content and thousand dollars)

State	2014			2015		
		Shipments			Shipments	
	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	272	273	21,400	270	270	23,300
California	1,110	1,110	81,700	1,010	1,010	87,500
Illinois	596	596	49,300	546	546	46,700
Louisiana	1,490	1,490	126,000	1,530	1,530	136,000
New Mexico	18	18	818	11	11	508
Ohio	131	130	16,200	125	125	16,000
Texas	3,280	3,300	292,000	3,250	3,250	338,000
Washington	159	168	7,290	150	150	6,920
Wyoming	603	603	22,900	599	601	22,500
Other[2]	1,390 r	1,400	110,000	1,400	1,420	103,000
Total	9,050 r	9,080	727,000	8,890	8,910	781,000

[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	2014		2015	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	220	219	193	194
Natural gas	13	13	13	13
Total	233	232	207	207
PAD 2:				
Petroleum and coke	1,290	1,280	1,320	1,320
Natural gas	8	8	13	13
Total	1,300	1,290	1,330	1,330
PAD 3:				
Petroleum and coke	5,110	5,130	5,080	5,090
Natural gas	414	416	395	395
Total	5,530 r	5,540	5,480	5,480
PAD 4 and PAD 5:				
Petroleum and coke	1,430 r	1,460	1,320	1,330
Natural gas	565	564	561	563
Total	1,990	2,020	1,880	1,890
Grand total	9,050 r	9,080	8,890	8,910
Of which:				
Petroleum and coke	8,040	8,080	7,910	7,930
Natural gas	1,000	1,000	982	984

[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, sulfur content and thousand dollars)

Type of plant	2014	2015
Copper[2]	497 r	553
Zinc, lead, and molybdenum	90 r	93
Total:		
Quantity	587	646
Value	92,100	75,500

[r]Revised.
[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, sulfur content)

Type	2014	2015
Elemental sulfur:		
Shipments	9,080	8,910
Exports	2,010 r	1,850
Imports[e]	2,370	2,240
Total	9,450	9,310
Byproduct sulfuric acid:		
Shipments	587	646
Exports[2]	52	56
Imports[2]	1,000 r	1,160
Total	1,540 r	1,750
Grand total	11,000	11,100

[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, sulfur content)

		Elemental sulfur[3]		Sulfuric acid (sulfur equivalent)		Total	
SIC[2] code	End use	2014	2015	2014	2015	2014	2015
102	Copper ores	--	--	251	278	251	278
1094	Uranium and vanadium ores	--	--	4	1	4	1
10	Other ores	--	--	64	70	64	70
26, 261	Pulp mills and paper products	W	W	129	124	129	124
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products[4]	W	W	74	141	74	141
281	Other inorganic chemicals	W	W	58	49	58	49
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	6	6	6	6
284	Soaps and detergents	--	--	2	5	2	5
286	Industrial organic chemicals	--	--	19	27	19	27
2873	Nitrogenous fertilizers	--	--	175	198	175	198
2874	Phosphatic fertilizers	--	--	4,810	4,610	4,810	4,610
2879	Pesticides	--	--	8	8	8	8
287	Other agricultural chemicals	1,970	2,140	51	34	2,020	2,170
2892	Explosives	--	--	7	8	7	8
2899	Water-treating compounds	--	--	34	32	34	32
28	Other chemical products	--	--	54	54	54	54
29, 291	Petroleum refining and other petroleum and coal products	2,120	2,250	410 r	428	2,530 r	2,680
331	Steel pickling	--	--	11	11	11	11
3691	Storage batteries (acid)	--	--	21	22	21	22
	Exported sulfuric acid	--	--	77	72	77	72
	Total identified	4,090	4,390	6,270 r	6,180	10,400 r	10,600
	Unidentified	1,170 r	1,320	145 r	139	1,310 r	1,460
	Grand total	5,250 r	5,710	6,410 r	6,320	11,700 r	12,000

[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]Standard Industrial Classification.
[3]Does not include elemental sulfur used for production of sulfuric acid.
[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	2014		2015	
	Quantity	Value	Quantity	Value
Brazil	862	120,000	760	101,000
Canada	21	11,200	70	10,900
China	298	48,200	253	42,200
Mexico	113 r	16,800 r	204	30,900
Morocco	332	42,100	217	31,300
New Caledonia	215 r	32,400 r	137	17,500
Other	164 r	44,000 r	206	46,900
Total	2,010 r	315,000 r	1,850	281,000

r Revised.

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	2014		2015	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	108,000 r	$10,100	114,000	$11,500
Curacao	4,030	289	1,100	71
Dominican Republic	3,620	205	2,970	298
Ireland	3,110	1,530	13,300	6,350
Israel	4,320	4,210	3,370	3,150
Jamaica	4,130	257	2,310	163
Malaysia	43	32	1,110	156
Mexico	6,290	1,790	6,680	1,230
Netherlands	2,010	202	17	7
Panama	2,120	180	3,150	312
Saudi Arabia	6,160	727	1,940	4,250
Taiwan	1,080	141	3,460	495
Trinidad and Tobago	12,300	926	4,370	417
Venezuela	291	69	8,100	651
Other	3,200 r	1,140 r	5,240	1,580
Total	160,000 r	21,800	172,000	30,700

r Revised.

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	2014 Quantity	2014 Value[2]	2015 Quantity	2015 Value[2]
Canada	1,880 [e]	84,100 [r]	1,860 [e]	87,100
Mexico	318	28,500	190	16,500
Venezuela	106	7,480	20	425
Other	65 [r]	14,100	169	31,600
Total	2,370 [e]	134,000	2,240 [e]	136,000

[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	2014 Quantity (metric tons)	2014 Value[2] (thousands)	2015 Quantity (metric tons)	2015 Value[2] (thousands)
Belgium	26,900	$510	18,100	$656
Brazil	597	402	5,110	2,060
Canada	1,870,000 [r]	116,000 [r]	2,070,000	124,000
Chile	--	--	10,000	673
China	828	802	1,360	1,230
Ecuador	1,700	1,260	--	--
Finland	26,400	716	189,000	8,350
Germany	78,700	3,380	107,000	4,050
Iraq	3,730	2,560	1,970	648
Libya	1,150	901	152	90
Mexico	658,000	35,800	768,000	41,000
Norway	--	--	13,700	784
Peru	--	--	36,300	760
Poland	78,800	2,580	51,300	2,830
Saudi Arabia	9,360	6,550	10,400	3,610
Spain	164,000	8,770	155,000	10,200
Sweden	146,000	6,720	96,900	3,880
Taiwan	3,520	2,810	3,120	2,490
Other	735 [r]	441 [r]	1,550	797
Total	3,070,000 [r]	190,000 [r]	3,540,000	208,000

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

(Thousand metric tons)

Country and source[3]	2011	2012	2013	2014	2015
Australia, byproduct:					
Metallurgy	800	800	810	810	810
Petroleum	60	60	90	90	90
Total	860	860	900	900	900
Belgium:					
Byproduct, all forms, unspecified	175	175	175	175	175
Elemental	225	225	225	225	225
Total	400	400	400	400	400
Brazil, byproduct:					
Metallurgy	322 [4]	275 [4]	324 [4]	287 [r, 4]	290
Petroleum	170 [4]	223 [4]	218 [4]	240 [r, 4]	240
Total	492 [4]	497 [4]	542 [4]	527 [r, 4]	530
Canada, byproduct:[4]					
Metallurgy	609	638	699	649	570 [p]
Natural gas, petroleum, oil sands	5,914	5,545	5,666	5,265	5,210 [p]
Total	6,523	6,183	6,365	5,914	5,780 [p]
Chile, byproduct, metallurgy	1,723 [4]	1,681 [4]	1,700	1,700	1,700
China:					
Byproduct, all sources, unspecified	3,300	3,300	2,600	2,840	2,800
Elemental	1,100	1,200	930	1,000	1,000
Pyrites	5,300	5,400	4,580	5,000	5,000
Total	9,700	9,900	8,110	8,840	8,800
Finland:					
Byproduct:					
Metallurgy	280	280	280	280	280
Petroleum	133	130	130	130	130
Pyrites	338	330	330	330	330
Total	751	740	740	740	740
France, byproduct, natural gas and petroleum	650	650	400	400	400
Germany, byproduct:					
Metallurgy	2,394 [4]	2,373 [4]	2,400	2,400	2,400
Natural gas and petroleum	1,514 [4]	1,445 [4]	1,400	1,400	1,400
Total	3,908 [4]	3,818 [4]	3,800	3,800	3,800
India:[5]					
Byproduct:					
Metallurgy (from fertilizer plants)	1,000	1,209 [4]	1,200	1,200	1,200
Natural gas and petroleum	1,600	1,600	1,600	1,500	1,500
Pyrites	30	30	30	30	30
Total	2,630	2,840	2,830	2,730	2,730
Iran, byproduct:					
Metallurgy	75	90	95	95 [r]	95
Natural gas and petroleum	1,575 [4]	2,000	2,100	2,100 [r]	2,100
Total	1,650 [4]	2,090	2,200	2,200 [r]	2,200
Italy, byproduct:					
Metallurgy	90	90	90	90	90
Petroleum	650	650	650	650	650
Total	740	740	740	740	740
Japan, byproduct:					
Metallurgy	1,450	1,500	1,500	1,500	1,500
Petroleum	1,755 [4]	1,747 [4]	1,779 [4]	1,751 [4]	1,750
Total	3,205 [4]	3,247 [4]	3,279 [4]	3,251 [4]	3,250
Kazakhstan, byproduct:					
Metallurgy	300	300	300	320	320
Natural gas and petroleum	2,400	2,151 [4]	2,443 [4]	2,455 [4]	2,500
Total	2,700	2,451 [4]	2,743 [4]	2,775 [4]	2,820
Korea, Republic of, byproduct, natural gas and petroleum	1,200	1,350	1,400	1,400	1,400
Kuwait, byproduct, petroleum	825	900 [r]	850	800	850

See footnotes at end of table.

TABLE 11—Continued

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

(Thousand metric tons)

Country and source[3]	2011	2012	2013	2014	2015
Mexico, byproduct:					
Metallurgy	800	800	810	810	810
Natural gas and petroleum	636 [4]	592 [4]	620 [4]	603 [4]	600
Total	1,440	1,390	1,430	1,410	1,410
Netherlands, byproduct:					
Metallurgy	115	115	115	115	115
Petroleum	400	400	400	400	400
Total	515	515	515	515	515
Poland:[6]					
Byproduct:					
Metallurgy	250	250	250	250	250
Natural gas	24	25	24	24	24
Petroleum (oil refineries and coking plants)	235 [4]	260 [4]	259	260	260
All sources, unspecified	1 [4]	(7) [4]	1	1	1
Frasch	657 [4]	677 [4]	526 [4]	605 [4]	600
Total[4]	1,166	1,212	1,060	1,140	1,135
Qatar, byproduct, natural gas	850	820	820	850	850
Russia:					
Byproduct:					
Metallurgy	200	300	300	200	200
Natural gas	6,488 [4]	6,416 [4]	5,977 [4]	5,859 [4]	5,900
Petroleum	600	700	700	500	500
Native	69 [4]	69 [4]	123 [4]	120	120
Pyrites	200	200	200	180	180
Total	7,557 [4]	7,685 [4]	7,300 [4]	6,859 [4]	6,900
Saudi Arabia, byproduct, all sources	4,579 [4]	4,092 [4]	3,900 [4]	4,400	4,900
United Arab Emirates, byproduct, natural gas and petroleum	1,885 [4]	1,900	2,000	2,400	2,400
United States, byproduct:[4]					
Metallurgy	720	586	616	587	646
Natural gas	1,140	1,040	1,020	1,000	982
Petroleum	7,090	7,370	7,570	8,040	7,910
Total	8,950	9,000	9,210	9,630	9,540
Uzbekistan, byproduct:					
Metallurgy	170	170	175	170	170
Natural gas and petroleum	350	370	380	370	370
Total	520	540	555	540	540
Venezuela, byproduct, natural gas and petroleum	800	800	800	700	700
Other:					
Byproduct:					
Metallurgy	1,270	808	825	825	825
Natural gas, petroleum, oil sands, undifferentiated	247	444	312 r	320 r	300
Petroleum	1,180	1,180	1,100	1,120 r	1,120
All forms and sources, unspecified	707 r	791 r	914 r	1,020 r	1,120
Native and elemental	267	290	280 r	261 r	244
Pyrites	35	32	28	25	25
Total	3,710 r	3,540 r	3,460 r	3,570 r	3,630
Grand total	69,900 r	69,800 r	68,000 r	69,100	69,500
Of which:					
Byproduct:					
Metallurgy	12,600 r	12,300 r	12,500 r	12,300 r	12,300
Natural gas	8,500	8,300	7,840	7,730	7,760
Natural gas, petroleum, oil sands, undifferentiated	18,800	18,800	19,100	18,900 r	18,900
Petroleum	13,100 r	13,600	13,800	14,000	13,900
All forms and sources, unspecified	8,760 r	8,360 r	7,590 r	8,430 r	8,990
Frasch	657	677	526	605	600
Native and elemental	1,660	1,780	1,560 r	1,610 r	1,590
Pyrites	5,900	5,990	5,170	5,570	5,570

See footnotes at end of table.

TABLE 11—Continued

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

(Thousand metric tons)

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

[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 November 16, 2017.

[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 product 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 country of the crude product from which the sulfur is extracted.

[4]Reported figure.

[5]Data for fiscal year ending March 31 of the year stated.

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

[7]Less than ½ unit.