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TITANIUM [ADVANCE RELEASE]

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Titanium

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In 2017, there were three producers of titanium mineral concentrates in the United States. The United States was 92% and 88% import reliant, as a percentage of apparent consumption, for titanium mineral concentrates and titanium sponge, respectively. The United States continued to be a net exporter of titanium dioxide (TiO_2) pigment and wrought titanium metal products. The leading sources of imported titanium mineral concentrates were, in descending order, South Africa, Australia, Madagascar, and Mozambique (table 11). Domestic production of TiO_2 pigment increased by 2% compared with that of 2016 (table 5). U.S. consumption of titanium used in steel and other alloys increased by 5% from that of 2016 (table 7). World production of titanium mineral concentrates in 2017 was about 11.6 million metric tons (Mt), a decrease of 5% from revised totals for 2016 (table 14).

Titanium is the ninth most abundant element in the earth's crust and can be found in nearly all rocks and sediments. It is a lithophile element with a strong affinity for oxygen and is not found as a pure metal in nature. Titanium was first isolated as a pure metal in 1910, but it wasn't until 1948 that metal was produced commercially using the Kroll process (named after its developer, William Kroll) to reduce titanium tetrachloride ($TiCl_4$) with magnesium to produce titanium metal.

Production

Titanium industry data for this report were collected by the U.S. Geological Survey (USGS) from annual and quarterly surveys of domestic titanium operations. In 2017, the USGS annual survey canvassed titanium mineral and pigment producers. Three producers of titanium mineral concentrates responded. Of the five active domestic TiO_2 pigment operations, three responded. Production data for the operations that did not respond were estimated on the basis of prior year production levels and industry trends. Production data for titanium ingot and mill products were aggregated from a quarterly survey of producers.

Mineral Concentrates.—Titanium minerals and materials of economic importance include ilmenite, leucoxene, rutile, synthetic rutile, and titanium slag. Mining of titanium minerals is usually performed using dredging and dry surface mining techniques for the recovery of heavy minerals, including titanium minerals. Spiral separation by gravity is used to isolate the heavy-mineral suite, and magnetic and high-tension separation circuits are used to separate the heavy-mineral constituents. Ilmenite and rutile are the two principal minerals for titanium. Ilmenite is the most abundant titanium mineral with a contained TiO_2 content ranging from 35% to 65%. Rutile, naturally occurring TiO_2, has the highest TiO_2 content but is less abundant. Ilmenite is often processed to produce a synthetic rutile or titanium slag. Although numerous technologies are used to produce synthetic rutile, nearly all are based on either selective leaching or thermal reduction of iron and other impurities in ilmenite.

U.S. mineral concentrate producers were The Chemours Co. (Wilmington, DE), Southern Ionics Minerals, LLC (Patterson, GA), and Twin Pines Minerals LLC (Starke, FL). Chemours' mining operations near Starke, FL, produced a mixed product containing ilmenite, leucoxene, and rutile that was used as a feedstock in Chemours' TiO_2 pigment plants. Southern Ionics' operations included the Mission Mine and a mineral-sands processor in Charlton County, in southern Georgia. Twin Pines Minerals LLC (Starke, FL) was reprocessing existing tailings from Chemours operations to extract titanium mineral concentrates and zircon.

TiO_2 Pigment.—TiO_2 pigment is produced from titanium mineral concentrates by either the chloride process or the sulfate process. In the chloride process, natural rutile, synthetic rutile, chloride-grade ilmenite, or titanium slag is converted to $TiCl_4$ by chlorination in the presence of petroleum coke. Titanium tetrachloride is oxidized with air or oxygen at about 1,000 degrees Celsius, and the resulting TiO_2 is calcined to remove residual chlorine and any hydrochloric acid that may have formed during the reaction. Aluminum chloride, added to the $TiCl_4$, ensures that virtually all the titanium is oxidized into the rutile crystal structure, rather than its polymorph anatase. In the sulfate process, ilmenite or titanium slag is reacted with sulfuric acid. Titanium hydroxide is then precipitated by hydrolysis, filtered, and calcined. Either process may be used to produce pigment; the decision of which process to use is based on numerous factors, including raw material availability, freight costs, and waste disposal costs. In finishing operations, the crude form of the pigment is milled to produce a controlled particle-size distribution and surface treated or coated to improve its functional behavior in various media. Some typical surface treatments include alumina, organic compounds, and silica. The TiO_2 pigment produced is categorized by crystal form as either anatase or rutile. Rutile pigment is less reactive with the binders in paint when exposed to sunlight than is the anatase pigment and is preferred for use in outdoor paints. Anatase pigment has a bluer tone than rutile, is somewhat softer, and is used mainly in indoor paints and in paper manufacturing. Depending on how it is produced and subsequently finished, TiO_2 pigment can have significantly different functional properties, including dispersion, durability, opacity, and tinting.

U.S. production of TiO_2 pigment was 1.26 Mt in 2017, a 2% increase compared with that of 2016 (table 5). U.S. producers of TiO_2 pigment using the chloride process were Cristal Global (a subsidiary of National Titanium Dioxide Company Ltd.), The Chemours Co., Louisiana Pigment Co. L.P. (a joint venture of Kronos Worldwide, Inc. and Venator Materials Plc), and Tronox Ltd. (table 4). TOR Minerals International, Inc. produced a buff TiO_2 pigment from finely ground synthetic rutile.

Metal.—In commercial production of titanium metal, titanium-containing mineral concentrates are chlorinated to

produce $TiCl_4$, which is then reduced with magnesium (Kroll process) or sodium (Hunter process) to produce a commercially pure titanium metal. The metal formed has a porous appearance and is referred to as sponge. Titanium ingot and slab are produced by melting titanium sponge and (or) scrap, usually with other alloying elements, such as aluminum and vanadium. Electron-beam, plasma-arc, scull, and vacuum-arc remelting are the commercial methods used to produce ingot and slab. Titanium mill products are formed by drawing, forging, and rolling of titanium into products of various sizes and shapes. These mill products include billet, pipe and tube, plate, rod and bar, sheet, strip, and wire. Titanium castings are produced by investment casting and rammed graphite mold casting.

In 2017, U.S. producers of titanium sponge were Honeywell Electronic Materials Inc. (Salt Lake City, UT) and Titanium Metals Corp. (Timet) (table 2), a subsidiary of Precision Castparts Corp. (Portland, OR). Timet's Henderson, NV, plant produced titanium sponge using the Kroll process. Honeywell Electronic Materials used the Hunter process to produce titanium sponge as feed for the company's production of electronic-grade titanium. A second plant that produced titanium sponge by the Kroll process, in Rowley, UT, was idled by Allegheny Technologies Inc. (ATI) in 2016. ATI reported that it was able to acquire sponge under long-term supply agreements at prices lower than its production costs at Rowley. The facility was idled so that it could be restarted if supported by market conditions (Allegheny Technologies Inc., 2016). Data on domestic production of titanium sponge were withheld to avoid disclosing company proprietary data. In 2017, U.S. production of titanium ingot increased by 24% and mill shipments were almost unchanged from those of 2016 (table 3).

Ferrotitanium is usually produced by induction melting of titanium scrap with iron or steel but may be produced through the aluminothermic reduction of ilmenite. The two grades of ferrotitanium that are normally produced contain 40% and 70% titanium, respectively. U.S. producers of ferrotitanium were Arconic Inc. (Canton, OH) with a capacity of 7,250 metric tons per year (t/yr) and Global Titanium Inc. (Detroit, MI) with a capacity of over 10,000 t/yr. Data on production of ferrotitanium were not available.

Mergers, Acquisitions, and Divestitures.—In August, Huntsman International LLC (The Woodlands, TX) completed the divestiture of its TiO_2 pigment and additive businesses. The new company, Venator Materials Plc, was headquartered in Stockton-On-Tees, United Kingdom, with seven TiO_2 pigment plants in Europe and Asia with a global capacity of 732,000 t/yr. It also had a 50% ownership of Louisiana Pigments Company L.P. (Lake Charles, LA), with a capacity of 150,000 t/yr, owned jointly with Kronos Worldwide, Inc. (Huntsman International LLC, 2017b; Venator Materials Plc, 2018a, p. 13).

Consumption

Mineral Concentrates.—Based on TiO_2 content, domestic consumption of titanium mineral concentrates was 1.41 Mt, a slight increase compared with that of 2016 (table 6). Consumption data for titanium mineral concentrates were estimated by the USGS owing to insufficient response by industry to the voluntary survey for consumption data.

TiO_2 Pigment.—Domestic production of TiO_2 pigment increased by 2%, and apparent domestic consumption (not accounting for changes in inventory) increased by 4% from that of 2016 (table 5). The leading uses of TiO_2 pigment, based on TiO_2 pigment shipments in the United States by domestic producers, were paint and coatings (68.5%), plastics and rubber (25.0%), and paper (4.5%). Other uses (2.0%) included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules (table 8).

Metal.—Titanium metal alloys are used for their high strength-to-weight ratio and corrosion resistance. The aerospace industry (80%) was the leading end use for mill products. In general, production of titanium mill products precedes aircraft deliveries by about 12 months. Other uses included consumer goods and the marine, medical, oil and gas, pulp and paper, and specialty chemical industries. In 2017, mill product shipments decreased 3% from those in 2016 (table 3). A significant quantity of titanium in the form of ferrotitanium, scrap, and sponge was consumed in the steel and nonferrous alloy industries. In the steel industry, titanium is used for deoxidation, grain-size control, and control and stabilization of carbon and nitrogen content. Titanium-intensive steels include interstitial, free, stainless, and high-strength low-alloy steels. Reported domestic consumption of titanium products in steel and other alloys was 11,600 metric tons (t), an increase of 5% from that of 2016 (table 7).

Stocks

Insufficient data were available to determine yearend consumer inventories of titanium mineral concentrates and TiO_2 pigment producer stocks. Reported yearend 2017 domestic stocks of sponge decreased by 47%, ingot stocks decreased by 46%, and scrap stocks decreased by 8% from those of 2016 (table 3).

Prices

Yearend titanium mineral concentrate prices are listed in table 9. In 2017, prices for bulk ilmenite rose throughout the year; rutile concentrates remained steady. Published prices for titanium slag were not available. Based on U.S. Census Bureau data, the value of slag imports from slag producing countries in December 2016 was $674 to $676 per metric ton and ended 2017 in a range from $590 to $689 per metric ton in December.

The U.S. Department of Labor, Bureau of Labor Statistics Producer Price Index (PPI) for TiO_2 pigment (June 1982 = 100) was 179 in January, decreased to 167 in March, and then gradually rose for the remainder of the year, ending at 205 in December. The monthly PPI for titanium mill products began at 162 in January and gradually rose to 170 in December.

Foreign Trade

Mineral Concentrates.—U.S. imports of titanium mineral concentrates included ilmenite, rutile, synthetic rutile, and titanium slag. The United States was heavily reliant on imports of titanium mineral concentrates because domestic consumption of titanium minerals greatly exceeded domestic production and capacity. In 2017, the TiO_2 content of imports was estimated to be 1.18 Mt, primarily in the form of ilmenite

(39%), titanium slag (35%), and rutile (27%). South Africa, Australia, Madagascar, and Mozambique were, in descending order of TiO_2 content, the leading import sources. The combined value for all forms of titanium mineral concentrate imports in 2017 was $650 million (table 11). Imports of titaniferous iron ore, containing less than 35% TiO_2, from Canada (classified as ilmenite by the U.S. Census Bureau), totaled 11,900 t in 2017. Exports of titanium mineral concentrates were minor relative to imports (tables 10, 11).

TiO_2 Pigment.—In 2017, the United States continued to be a net exporter of TiO_2 pigment, with exports exceeding imports by a ratio of 2.7 to 1. Exports of TiO_2 pigment were 634,000 t, a slight decrease compared with those of 2016. About 96% of TiO_2 pigment exports was in the form of finished pigment containing 80% or more TiO_2 content (table 10). During 2017, 239,000 t of TiO_2 pigment was imported, a decrease of 3% from that of 2016. The leading import sources of TiO_2 pigment were Canada (40%) and China (22%). About 80% of pigment imports was in the form of finished pigment containing more than 80% TiO_2 (table 13).

Metal.—Total imports of titanium metal, excluding ferrotitanium, increased by 39% from those in 2016. Imports of titanium metal were primarily in the form of waste and scrap (42%), sponge (40%), and wrought products and castings (14%). Japan supplied 79% of imported titanium sponge, Russia supplied 96% of imported titanium ingot, and the United Kingdom, Germany, Japan, and France were, in descending order, the leading sources of imported scrap. China (65%) was the leading source of titanium powder. Russia was the leading source of wrought products and castings. Imports of wrought products and castings were 8,650 t, an increase of 21% from revised 2016 totals.

Imports of ferrotitanium were 2,550 t, a decrease of 19% from those of 2016 (table 12). Exports of ferrotitanium were 2,420 t, an increase of 20% compared with those of 2016 (table 10).

World Review

Global consumption of TiO_2 pigments in 2018 was 6.48 Mt with a total capacity of about 7.7 million metric tons per year (Mt/yr), a 5% increase from 2016. The consuming end-use sectors were paint, varnish, and lacquer (55%), plastics and rubber (26%), paper (8%) and other (11%) (Adams, 2018a, p. 22, 26, 27).

Australia.—Iluka Resources Ltd. produced 135,000 t of rutile and 211,000 t of synthetic rutile from its operations in Australia, an increase of 24% and essentially unchanged, respectively, from the previous year. Iluka resumed mining activity at its Jacinth-Ambrosia Mine in South Australia that was idle from April 2016 to November 2017. The Cataby Project in Western Australia was approved with production expected to begin in the first half of 2019. Over a projected mine life of 8.5 years, production from the mine was anticipated to produce enough chloride-grade ilmenite to produce 200,000 t/yr of synthetic rutile (Iluka Resources Ltd., 2018, p. 19, 24–26).

In 2017, Tronox Ltd. produced 28,000 t of rutile from its Cooljarloo Mine in Western Australia, a decrease of 13% from 32,000 t produced in 2016. Synthetic rutile from Cooljarloo was 243,000 t, a 4% increase from 233,000 t produced in 2016. Heavy-mineral reserves at Tronox's operations in Western Australia were decreased by 4.3% from 2016 estimates. In 2017, reserves were 481 Mt of ore containing 11.1 Mt of heavy minerals, including 6.34 Mt of ilmenite and 509,000 t of rutile and leucoxene (Tronox Ltd., 2017, p. 36; 2018, p. 32, 34).

In February, Melior Resources Inc. announced plans to restart its Goondicum Mine. The mine had been placed on care-and-maintenance status in July 2015. Indicated mineral resources were 66 Mt containing ilmenite (3.4 Mt) and apatite (1.2 Mt). Average annual production was expected to be 160,000 t/yr of ilmenite and 40,000 t/yr of apatite over a mine life of 9 years, with operations expected to commence in late 2018 (Melior Resources Inc., 2017, 2018).

Sheffield Resources Ltd. continued its search for offtake agreements for its ilmenite and titanomagnetite products for its Thunderbird heavy-mineral-sands project. Production of ilmenite products in the initial year of production was expected to be about 200,000 t, increasing to an average of about 400,000 t in the first 10 years of production. Proved and probable reserves of leucoxene and ilmenite were 2.8 Mt. Sheffield was expecting Thunderbird to begin production in 2020 (Sheffield Resources Ltd., 2017, p. 9, 15, 19, 27).

Image Resources NL continued development of its Atlas and Boonanarring projects in the North Perth basin in Western Australia. Both projects consisted of dry open-cut pit and dredge mining schemes with reserves of 29.3 Mt containing ilmenite, leucoxene, and rutile. Image Resources had obtained offtake agreements for 100% of the heavy-mineral-concentrate production for the life of the project and was expecting the first production to begin in late 2018 (Image Resources NL, 2018, p. 4, 9, 20).

Canada.—Argex Titanium Inc. (Laval, Quebec) was continuing development of a new technology for production of chloride-based TiO_2 pigments. A technology center, expected to begin operations in 2018, would work on improving the technology and scaling the process to full-scale production by 2020 with an initial capacity of 30,000 t/yr (Argex Titanium Inc., 2017, p. 6, 7, 13).

China.—Imports of titanium mineral concentrates under the Harmonized System (HS) code 261400 totaled 3.07 Mt in 2017, an increase of 20% from those of 2016. The leading import countries, in decreasing order, were Mozambique, Australia, and Kenya. Imports of titanium-based pigments (HS codes 282300, 320611, 320619) totaled 248,000 t in 2017, an increase of 14% from those of 2016 (Global Trade Information Services, Inc., 2018).

Exports of titanium mineral concentrates (HS code 261400) totaled 22,100 t in 2017, an increase of 68% from 2016. Exports of titanium-based pigments (HS codes 282300, 320611, 320619) totaled 899,000 t in 2017, an increase of 14% from exports in 2016 (Global Trade Information Services, Inc., 2018).

According to Artikol, a TiO_2 market analyst, China's TiO_2 pigment production in 2017 totaled 2.87 Mt, an increase of 11% from that in 2016. Throughout 2017, Chinese Government enforcement under the Environment Protection Law, adopted in 2015, resulted in the permanent closure of plants with less than 60,000 t/yr of capacity, which accounted for 300,000 t/yr of TiO_2 pigment capacity. A total of 42 pigment producers were

active at yearend 2017, but the top 10 producers accounted for 65% of the 2017 production. Total capacity was 3.25 Mt/yr, of which 168,000 t/yr was at chloride-process plants (Adams, 2018a, p. 31, 33; TiO_2 Worldwide Update, 2018, p. 4, 5). Lomon Billions Group Co. Ltd., the largest TiO_2 pigment producer in China with 705,000 t/yr of capacity, produced almost 600,000 t in 2017, 90% of which was made by using the sulfate process (Griffin, 2018, p. 5, 7).

Finland.—On January 30, a fire significantly damaged Huntsman's TiO_2 pigment facility at Pori, Finland. Subsequently, Huntsman announced its intention to repair the facility. The plant formerly had a capacity of 130,000 t/yr and provided 15% of Huntsman's capacity (Huntsman International LLC, 2017c). By yearend, the new owner, Venator Materials Plc, was not expected to bring the plant to its former capacity until 2020 (Venator Materials Plc, 2018b, p. 2−3).

France.—In March, Huntsman announced the closure of the remaining TiO_2 operations in Calais. In 2015, the operation's 100,000-t/yr TiO_2 pigment plant was idled, but finishing operations continued. The plant accounted for 13% of Huntsman's European TiO_2 pigment capacity (Huntsman International LLC, 2017a).

Iran.—In May, the Iranian Mines and Mining Industries Development and Renovation Organization (IMIDRO) began commissioning production of ilmenite from its Kahnuj Mine and mineral-processing operations in the Kernan Province. Construction began in late 2016, with an expected output of 130,000 t/yr of ilmenite and 70,000 t/yr of titanium slag. A pilot plant was producing pigments suitable for the domestic paint sector (Argus Media group—Argus Metals International, 2017).

Japan.—In 2017, Japan produced 20,900 t of titanium ingots, slightly more than the revised total of 20,000 t in 2016. Titanium mill shipments increased by 11% to 18,200 t owing to an increased demand by the aerospace and electrolysis sectors in the domestic market and increased exports to China and Europe for the land-based turbine and heat-exchanger markets (Roskill's Letter from Japan, 2018b).

Production of TiO_2 pigments totaled 192,000 t in 2017, an increase of 7% from that of 2016 owing to higher output of rutile-based pigments. Japan's TiO_2 production capacity was about 307,000 t, and three of the five producers held 90% of the capacity (Roskill's Letter from Japan, 2018a).

Kenya.—Base Resources Ltd. (Australia) produced 470,000 t of ilmenite and 91,500 t of rutile in 2017, a slight increase of ilmenite and a 4% increase of rutile production from 2016. The wet concentrator plant was scheduled to be taken offline for 1 month in March 2018 to allow for plant modifications and equipment upgrades (Base Resources Ltd., 2017a, p. 6; 2018, p. 6).

Madagascar.—Base Resources Ltd. announced an agreement with World Titane Holdings Ltd. (Mauritius) to acquire an 85% interest in the Toliara Sands Project in southwestern Madagascar. The acquisition was expected to be completed in early 2018 with production to begin in 2021 (Base Resources Ltd., 2017b, p. 1).

Mozambique.—Kenmare Resources plc produced 998,000 t of ilmenite and 9,100 t of rutile in 2017, increases of 11% and 17%, respectively, from that of 2016. The company attributed the increased production of heavy-mineral concentrates to improved dredge and dry mining techniques (Kenmare Resources plc, 2018, p. 25, 26).

Norway.—Titanium slag production at TiZir Ltd. increased by 75% in 2017 to 181,000 t, owing to an extended shutdown in 2016 (TiZir Ltd., 2018, p. 4).

In October, Norsk Mining ASA completed a prefeasibility study of its Engebø project in southwestern Norway. Engebø is a hard rock rutile and garnet deposit with measured and indicated resources of 92.5 Mt containing 3.89% TiO_2 and 43.7% garnet. Findings from the study supported a combination of open pit and underground mining for a period 16 and 13 years, respectively, with an expected production rate of more than 33,000 t/yr of rutile and 260,000 t/yr of garnet. Production was scheduled to begin in 2021 (Norsk Mining ASA, 2017, p. 11–12, 18, 25).

Russia.—Production of titanium sponge and ingots totaled 42,600 t and 62,200 t, respectively, and consumption was 10,000 t in 2017. The primary end-use sectors for titanium metal were aircraft manufacturing, engine and shipbuilding, and other industrial uses, accounting for 24%, 35%, and 20%, respectively, of consumption (Metz, 2018, p. 2−3, 6).

Saudi Arabia.—The Advanced Metal Industries Co. postponed the trial run of its titanium sponge project in Yanbu. Production at the facility, which was expected to have an initial capacity of 15,600 t/yr of titanium sponge, was delayed until the second half of 2018 owing to delays in the construction of the unit that was expected to produce titanium tetrachloride feedstock for the sponge plant (Argaam Investment Co., 2017).

Senegal.—Mineral Deposits Ltd. produced 492,441 t of ilmenite and 9,975 t of rutile and leucoxene at its Grand Côte Mine in 2017, an increase of 18% and 3%, respectively, from production in 2016 (TiZir Ltd., 2018, p. 2).

Sierra Leone.—Sierra Rutile, a subsidiary of Iluka, produced 57,600 t of ilmenite and 167,600 t of rutile in 2017, its first full year of production since being acquired in December 2016. Feasibility studies were ongoing to double mine capacity at the Lanti and the Gangama Mines. Dredging and dry mining expansions were expected to begin in 2019 (Iluka Resources Ltd., 2018, p. 27, 37).

South Africa.—Tronox decreased its reserves estimates at the Tronox KwaZulu-Natal (KZN) and Namakwa Sands operations by 5.9% to 864 Mt of ore containing 54.7 Mt of total heavy minerals. Mine-life expectancies of its KZN and Namakwa operations exceeded 12 and 25 years, respectively (Tronox Ltd., 2018, p. 30, 34).

Mineral Commodities Ltd.'s production of heavy-mineral concentrates at its Tormin Mine included 22,000 t of rutile-zircon mixed concentrate and 217,000 t of ilmenite concentrate. Production of rutile-zircon mixed concentrate decreased 61%, owing to lower ore grades, and ilmenite concentrate production increased slightly compared with that in 2016 (Mineral Commodities Ltd., 2018, p. 11–12).

Tanzania.—In October, Strandline Resources Ltd. completed a definitive feasibility study for its Fungoni heavy-mineral-sands project. Reserves were 12.3 Mt of ore grading 3.9% total heavy minerals. Strandline was anticipating production to begin in 2019 (Strandline Resources Ltd., 2018b, p. 6, 13). At yearend, the project had received an environmental certificate,

and the company had submitted a mining license application. (Strandline Resources Ltd., 2018a).

Ukraine.—In May, Velta LLC and the Commercial Metals Co. (CMC) (Irving, TX) signed a memorandum of intent to build a mining and processing complex at the Likarivske deposit in the Kirovohrad region. The project would have a mining and production capacity of 120,000 t/yr of ilmenite. Construction activities would begin once the required approvals were obtained (Velta LLC, 2017). Velta produced 215,000 t of ilmenite concentrates from its Byrzulivske Mine in 2017 (Perks, 2018).

Outlook

Global consumption for TiO_2 pigments is forecast to increase by 4.1% annually. Global production capacity of TiO_2 pigments is expected to increase to meet increased demand. The distribution of chloride-process versus sulfate-process TiO_2 pigment capacity is expected to reach parity by 2021 and is expected to be driven mainly by the expansion of chloride-process capacity in China (Adams, 2018a, p. 27; 2018b, p. 25, 26).

Supported by orders of commercial aircraft, which were up by 25% in 2017 from those of 2016, demand for titanium in the commercial aerospace industry is expected to increase through 2020 (Halford, 2018, p. 4, 9). The leading end-use sectors for industrial titanium are expected to be, in decreasing order, chemical processing, power generation, desalination, and other uses, increasing from 27,000 t at yearend 2017 to 32,500 t by 2021 (Bruneau, 2018, p. 34).

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TABLE 1
SALIENT TITANIUM STATISTICS[1]

		2013	2014	2015	2016	2017
United States:						
Mineral concentrates:						
Production[2]	metric tons	300,000	200,000	300,000	100,000	100,000
Imports for consumption	do.	1,480,000	1,380,000	1,440,000	1,420,000 r	1,570,000
Consumption[e, 3]	do.	1,820,000	1,790,000	1,720,000	1,740,000	1,760,000
Sponge metal:						
Imports for consumption	do.	19,900	17,700	20,700	16,200	24,100
Consumption	do.	26,500	26,400	31,200	34,100	37,400
Price, yearend[4]	dollars per pound	7.05–12.73 r	8.97–13.15 r	7.31–11.81 r	11.08–11.94 r	6.88–11.26
Titanium dioxide pigment:						
Production	metric tons	1,280,000	1,260,000	1,220,000	1,240,000	1,260,000
Imports for consumption	do.	213,000	224,000	221,000	247,000	239,000
Consumption, apparent[5]	do.	826,000	802,000	788,000	840,000 r	870,000
Producer Price Index, yearend[6]	(June 1982=100)	236	224	176	175	205
World, production:						
Ilmenite concentrate[7]	metric tons	10,400,000 r	10,400,000 r	9,540,000 r	9,550,000 r	9,090,000
Rutile concentrate, natural[8]	do.	629,000 r	660,000	762,000 r	886,000 r	803,000
Titanium slag[e]	do.	2,070,000	1,930,000	1,650,000	1,730,000	1,670,000

[e]Estimated. [r]Revised. do. Ditto.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Rounded to one significant digit to avoid disclosing company proprietary data.
[3]Does not include consumption used to produce synthetic rutile.
[4]Landed duty-paid unit based on U.S. imports for consumption.
[5]Production plus imports minus exports. Does not include stock changes.
[6]Source: U.S. Department of Labor, Bureau of Labor Statistics.
[7]Includes U.S. production of ilmenite and rutile rounded to one significant digit to avoid disclosing company proprietary data.
[8]U.S. production of rutile included with ilmenite to avoid disclosing company proprietary data.

TABLE 2
U.S. TITANIUM METAL PRODUCTION CAPACITY IN 2017[1, 2]

(Metric tons per year)

		Yearend capacity[e]	
Company	Plant location	Sponge	Ingot[3]
Alcoa Howmet	Whitehall, MI	--	3,200
Allegheny Technologies Inc.	Albany, OR	--	10,900
Do.	Monroe, NC	--	23,200
Do.	Richland, WA	--	10,000
Alloy Works LLC	Greensboro, NC	--	1,800
Arconic Inc.	Niles, OH	--	13,600
Honeywell Electronic Materials Inc.	Salt Lake City, UT	500	--
Perryman Co.	Houston, PA	--	1,800
Titanium Metals Corp.	Henderson, NV	12,600	12,300
Do.	Morgantown, PA	--	40,700
Do.	Vallejo, CA	--	800
Total		13,100	118,000

[e]Estimated. Do. Ditto. -- Zero.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Estimated operating capacity based on 7-day-per-week full production.
[3]Includes electron-beam, plasma-arc, and vacuum-arc remelting capacity.

TABLE 3
COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND[1]

(Metric tons)

Component	2016	2017
Production:		
Ingot	66,200	82,100
Mill products	38,200	38,000
Exports:		
Waste and scrap	9,720 r	9,450
Sponge	679 r	3,090
Other unwrought	9,460	11,700
Wrought products and castings	18,900 r	19,900
Total	38,700 r	44,200
Imports:		
Waste and scrap	18,500	25,200
Sponge	16,200	24,100
Other unwrought	2,080	2,830
Wrought products and castings	7,130 r	8,650
Total	43,900	60,800
Stocks, industry, yearend:		
Sponge	25,100	13,200
Scrap	16,500	15,200
Ingot	9,480	5,120
Consumption, reported:		
Sponge	34,100	37,400
Scrap	55,000	62,400
Ingot	56,200	67,800
Shipments, net:		
Ingot, producer	21,600	21,500
Mill products:		
Forging and extrusion billet	25,200	26,000
Other	12,800	11,000
Total	38,000	37,000
Castings	W	W
Receipts, scrap:		
Home	21,800	22,100
Purchased	41,100	48,600
Total	62,900	70,700

rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
U.S. PRODUCERS OF TITANIUM DIOXIDE PIGMENT IN 2017[1, 2, 3]

(Metric tons per year)

Company	Plant location	Yearend capacity[4]
Cristal Global	Ashtabula, OH	245,000
The Chemours Co.	De Lisle, MS	340,000
Do.	New Johnsonville, TN	400,000
Louisiana Pigment Co. L.P.	Lake Charles, LA	160,000
Tronox Ltd.	Hamilton, MS	225,000
Total		1,370,000

Do. Ditto.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to total shown.
[2]Estimated operating capacity based on 7-day-per-week full production.
[3]Table does not include TOR Minerals International, Inc.'s Corpus Christi, TX, production capacity of about 26,400 metric tons per year of buff TiO_2 pigment that is produced by refining and fine grinding of synthetic rutile.
[4]All plants use the chloride process to manufacture TiO_2 pigment.

TABLE 5
COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND[1]

Component		2016 Gross weight	2016 TiO_2 content	2017 Gross weight	2017 TiO_2 content
Production[2]	metric tons	1,240,000	1,170,000	1,260,000	1,190,000
Shipments:[3]					
Quantity	do.	1,260,000	1,190,000	1,280,000	1,210,000
Value	thousands	$2,760,000 r	XX	$3,240,000	XX
Exports	metric tons	651,000 r	617,000	634,000	596,000
Imports for consumption	do.	247,000	232,000	239,000	225,000
Consumption, apparent[e, 4]	do.	840,000 r	789,000 r	870,000	818,000

[e]Estimated. [r]Revised. do. Ditto. XX Not applicable.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits.
[2]Does not include production of buff pigment.
[3]Includes interplant transfers.
[4]Production plus imports minus exports. Does not include stock changes.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6
ESTIMATED U.S. CONSUMPTION OF TITANIUM MINERAL CONCENTRATES[1, 2]

(Metric tons)

Use	2016 Gross weight	2016 TiO_2 content	2017 Gross weight	2017 TiO_2 content
Pigment	1,640,000	NA	1,660,000	NA
Miscellaneous[3]	99,100	NA	92,100	NA
Total	1,740,000	1,390,000	1,760,000	1,410,000

NA Not available.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes a mixed product containing altered ilmenite, leucoxene, and rutile.
[3]Includes alloys, carbide, ceramics, chemicals, glass fibers, titanium metal, and welding-rod coatings and fluxes.

TABLE 7
U.S. CONSUMPTION OF TITANIUM IN STEEL AND OTHER ALLOYS[1, 2]

(Metric tons)

Use	2016	2017
Steel:		
Carbon steel	5,510	5,410
Stainless and heat-resisting steel	3,440	3,640
Other alloy steel[3]	593	735
Total steel	9,550	9,790
Cast irons	9	5
Superalloys	246	595
Alloys, other than above	1,140	1,130
Miscellaneous and unspecified	98	81
Grand total	11,000	11,600

[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes ferrotitanium, scrap, sponge, and other titanium additives.
[3]Includes high-strength low-alloy and tool steel.

TABLE 8
ESTIMATED U.S. DISTRIBUTION OF TITANIUM PIGMENT SHIPMENTS,
TITANIUM DIOXIDE CONTENT, BY INDUSTRY[1]

(Percent)

Industry	2016	2017
Paint, varnish, and lacquer	67.5	68.5
Paper	3.0	4.5
Plastics and rubber	25.0	25.0
Other[2]	4.5	2.0
Total	100.0	100.0

[1]Table includes data available through February 11, 2020. Does not include exports.
[2]Includes agricultural, building materials, ceramics, coated fabrics and textiles, cosmetics, food, and printing ink. Also includes shipments to distributors.

TABLE 9
YEAREND PRICES OF TITANIUM PRODUCTS

		2016	2017
Concentrate:			
Ilmenite, free on board (f.o.b.) Australian ports[1]	dollars per metric ton	100–110	160–185
Rutile, bagged, f.o.b. Australian ports[1]	do.	770–850	770–850
Rutile, bulk, f.o.b. Australian ports[1]	do.	710–770	710–770
Titanium slag, import, 80% to 95% TiO_2[2]	do.	674–676	590–689
Metal:			
Sponge import[2]	dollars per kilogram	11.08–11.94 [r]	6.88–11.26
Scrap, turnings, unprocessed[3]	do.	0.40–0.50	0.55–0.65
Ferrotitanium, 70% Ti[3]	do.	1.70–1.80	2.10–2.20
Mill products[4]	Producer Price Index	163	170
Titanium dioxide pigment[4]	do.	175	205

[r]Revised. do. Ditto.
[1]Source: Industrial Minerals.
[2]Landed duty-paid unit value based on U.S. imports for consumption from sponge-producing countries.
[3]Source: Platts Metals Week.
[4]June 1982=100. Source: U.S. Department of Labor, Bureau of Labor Statistics.

TABLE 10
U.S. EXPORTS OF TITANIUM, BY CLASS[1]

Class	HTS[2] code	2016 Quantity (metric tons)	2016 Value (thousands)	2017 Quantity (metric tons)	2017 Value (thousands)
Metal:					
Scrap	8108.30.0000	9,720	$25,600	9,450	$28,100
Unwrought:					
Sponge	8108.20.0010	697	5,400	3,090	28,100
Ingot	8108.20.0030	7,720	118,000	9,010	127,000
Other unwrought	8108.20.0090, 8108.20.0095	1,740	56,700	2,730	64,700
Wrought:					
Bloom, sheet bar, slab	8108.90.6020	3,090	96,100	3,480	105,000
Bar, rod, profile, wire	8108.90.6031	5,730	261,000	5,540	253,000
Other	8108.90.8000	10,100	1,020,000	10,900	1,110,000
Total		18,900	1,370,000	19,900	1,470,000
Ferrotitanium and ferrosilicon titanium	7202.91.0000	2,020	6,130	2,420	8,560
Ores and concentrates	2614.00.0000	7,330	9,830	8,940	12,300
Pigment:					
80% or more titanium dioxide pigment	3206.11.0000	633,000	1,330,000	608,000	1,480,000
Other titanium dioxide pigment	3206.19.0000	14,400	90,700	22,000	111,000
Unfinished titanium dioxide[3]	2823.00.0000	3,050	9,310	4,130	8,340
Total		651,000	1,430,000	634,000	1,600,000

[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Unmixed and not surface treated.

Source: U.S. Census Bureau.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM MINERAL CONCENTRATES, BY COUNTRY OR LOCALITY[1]

Concentrate and country or locality	HTS[2] code	2016 Quantity (metric tons)	2016 Value (thousands)	2017 Quantity (metric tons)	2017 Value (thousands)
Ilmenite:	2614.00.6020				
Australia		207,000	$23,800	229,000	$35,700
Madagascar		92,100	$15,700	198,000	$36,800
Mozambique		186,000	29,100	191,000	30,200
Senegal		72,000	11,500	65,100	10,200
Ukraine		20,200	2,720	65,900	9,730
Other		92,200 r	2,020 r	11,900	8,330
Total		669,000 r	84,800 r	760,000	131,000
Titanium slag:	2620.99.5000				
Australia		--	--	1,500	1,050
Canada		122,000	82,900	106,000	74,300
Norway		11,000	6,390	32,700	19,200
South Africa		269,000	165,000	339,000	210,000
Total		402,000	254,000	479,000	305,000
Rutile, natural:	2614.00.6040				
Australia		62,700	40,000	84,200	46,900
Kenya		22,900	17,300	30,500	22,000
Sierra Leone		27,700	19,600	10,200	7,710
South Africa		135,000	82,000	140,000	87,600
Other		18,800 r	12,900 r	23,700	16,600
Total		267,000	172,000	289,000	181,000
Rutile, synthetic:	2614.00.3000				
Australia		68,900	46,400	33,600	24,100
Other		13,700	12,100	11,500	9,570
Total		82,700	58,500	45,100	33,600
Titaniferous iron ore, Canada[3]	2614.00.6020	15,200	1,430	11,900	8,330

rRevised. -- Zero.

[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel-furnace flux. Titaniferous iron ore from Canada is classified as ilmenite under the HTS.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY OR LOCALITY[1]

Class and country or locality	HTS[2] code	2016 Quantity (metric tons)	2016 Value (thousands)	2017 Quantity (metric tons)	2017 Value (thousands)
Waste and scrap:	8108.30.0000				
Canada		1,260	$4,520	1,510	$4,190
China		300	2,550	459	4,030
France		2,250	14,700	2,940	11,700
Germany		2,690	13,900	4,020	18,700
Israel		352	1,850	274	762
Italy		1,110	3,370	1,860	6,080
Japan		2,430	10,300	3,550	13,800
Korea, Republic of		1,290	5,440	1,150	5,030
Mexico		634	2,320	813	3,040
Taiwan		132	567	222	845
United Kingdom		4,480	27,900	5,730	44,300
Other		1,560	6,240	2,710	9,780
Total		18,500	93,600	25,200	122,000
Unwrought:					
Sponge:	8108.20.0010				
China		49	415	17	193
Japan		15,800	145,000	19,400	178,000
Kazakhstan[e]		45	374	2,510	15,900
Russia		202	1,950	136	1,090
Ukraine		44	323	1,970	11,700
Other		5 [r]	112 [r]	109	968
Total		16,200	148,000	24,100	208,000
Ingot:	8108.20.0030				
Japan		41	3,500	(3)	29
Russia		620	11,500	1,490	22,600
Other		28	151	62	387
Total		690 [r]	15,100	1,550	23,000
Powder:	8108.20.0015				
Canada		27	5,720	39	7,400
China		115	2,000	102	1,870
Germany		11	3,060	10	2,590
Other		8	1,180	6	914
Total		161	12,000	157	12,800
Other:	8108.20.0095				
France		54	2,120	6	267
Germany		15	173	(3)	98
Russia		1,010	22,700	895	21,900
United Kingdom		140	6,280	95	3,760
Other		14	647	124	3,760
Total		1,230	31,900	1,120	29,700
Wrought products and castings:[4]	8108.90.3030, 8108.90.3060, 8108.90.6020, 8108.90.6031, 8108.90.6045, 8108.90.6060, 8108.90.6075				
Canada		159 [r]	9,590 [r]	127	11,700
China		929 [r]	40,500	1,150	43,700
Japan		707 [r]	17,900 [r]	720	19,300
Russia		3,210	124,000	3,980	156,000
United Kingdom		484 [r]	51,200 [r]	424	38,900
Other		1,650 [r]	106,000 [r]	2,240	135,000
Total		7,130 [r]	348,000 [r]	8,650	404,000
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3,140	7,840	2,550	7,570

[e]Estimated. [r]Revised.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Less than ½ unit.
[4]Includes bar, bloom, castings, foil, pipe, plate, profile, rod, sheet, sheet bar, slab, strip, tube, wire, and other.

Source: U.S. Census Bureau.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENT, BY COUNTRY OR LOCALITY[1]

Country or locality	HTS[2] code	2016 Quantity (metric tons)	2016 Value (thousands)	2017 Quantity (metric tons)	2017 Value (thousands)
80% or more titanium dioxide pigment:	3206.11.0000				
Australia		1,180	$2,770	556	$1,230
Belgium		5,100	10,400	8,930	20,200
Canada		67,200 r	149,000 r	85,600	207,000
China		42,700	72,500	36,600	84,100
Czechia		1,610	3,680	3,440	8,510
Finland		8,290	18,600	1,840	7,030
France		2,620	6,020	548	2,170
Germany		15,000	33,900	17,400	45,000
India		881	1,420	1,310	2,310
Italy		1,780	3,730	2,540	7,440
Japan		6,500	23,300 r	6,600	24,100
Malaysia		57	97	409	603
Mexico		14,400	27,900	11,400	24,300
Netherlands		500	1,620	462	1,540
Norway		3,390	6,780	1,890	4,080
Slovenia		852	1,530	483	1,020
Spain		7,470	14,100	5,880	12,100
Ukraine		3,150	4,870	3,230	6,080
United Kingdom		2,040	4,000	908	1,900
Other		685 r	1,250 r	1,080	2,860
Total		185,000	387,000 r	191,000	463,000
Other titanium dioxide:	3206.19.0000				
Canada		9,220	21,700	10,800	25,800
China		1,830	5,420	1,380	5,340
Colombia		22	59	317	793
France		181	566	216	1,030
Germany		190	2,550	291	4,270
India		318	1,270	258	1,120
Israel		3	344	72	1,020
Italy		460	1,880	807	2,260
Japan		273 r	4,460 r	152	2,520
Korea, Republic of		21	592	17	459
Mexico		58	250	77	315
Spain		38	205	14	96
United Kingdom		88	2,710	100	3,140
Other		105	1,260	137	1,500
Total		12,800	43,300 r	14,700	49,600
Unfinished titanium dioxide:[3]	2823.00.0000				
China		24,400	41,500	14,400	34,200
Czechia		2,870	5,800	2,570	5,620
Finland		2,860	9,040	1,530	5,150
France		6,060	14,300	3,870	10,300
Germany		5,300	15,400	6,460	19,900
India		2,090	3,720	2,210	4,580
Italy		2,220	5,910	--	--
Japan		369	4,090	323	3,030
Korea, Republic of		868	2,090	360	1,050
Other		1,690	4,230	1,760	4,360
Total		48,800	106,000	33,400	88,100
Grand total		247,000	536,000 r	239,000	601,000

rRevised. -- Zero.
[1]Table includes data available through February 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Unmixed and not surface treated.

Source: U.S. Census Bureau.

TABLE 14
TITANIUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY OR LOCALITY[1]

(Metric tons, gross weight)

Concentrate and country or locality	2013	2014	2015	2016	2017
Ilmenite and leucoxene:[2, 3]					
Australia	1,562,000 r	1,250,000	1,156,000 r	1,300,000	1,213,000
Brazil[4]	78,264 r	81,278 r	78,991 r	80,000 r, e	80,000 e
China	3,850,000 r	4,240,000 r	3,910,000 r	3,800,000 r	3,830,000
Egypt	20,000	--	--	--	-- e
India[e]	436,000	728,000 r	849,000 r	785,000 r	500,000
Indonesia	26,633 r	1,485 r	23,000 e	20,000	20,000 e
Kazakhstan	10,000 e	10,000 e	8,000 e	14,000 r	9,400
Kenya	5,539 r	368,239 r	444,999 r	468,903 r	470,317
Madagascar	530,421 r	333,736 r	177,998 r	222,227 r	180,022
Malaysia	16,043 r	8,159 r	5,814 r	30,400	29,000
Mozambique	780,000 e	926,800 r	828,893 r	1,340,330 r	998,200
Norway	826,000	864,000	429,800 r	438,600 r	360,000
Russia	150,458 r	178,426 r	193,236 r	--	--
Senegal	--	100,590 r	427,690 r	416,249 r	492,441
Sierra Leone	32,300 e	35,838 r	37,633 r	50,000 r	58,000
Sri Lanka	44,129 r	32,972 r	39,439 r	32,700	30,000 e
Ukraine	670,000 e	450,000 e	350,000 e	350,000 e	392,000
United States[4, 5]	300,000 e	200,000 e	300,000 e	100,000	100,000
Vietnam[6]	1,025,800 r	558,000	282,000	102,000 r	329,000
Total[7]	10,400,000 r	10,400,000 r	9,540,000 r	9,550,000 r	9,090,000
Rutile:[3]					
Australia	232,000	212,000	320,000	400,000	300,000
Brazil[4]	2,246 r	2,038 r	2,222 r	2,000	2,000 e
India[e]	14,500 r	18,600 r	22,200 r	16,400 r	10,000
Kenya	152	59,348 r	78,947 r	88,288 r	91,456
Madagascar[e]	11,000	6,900	4,800	4,800	5,000
Malaysia	5,983 r	3,069 r	198	200	200 e
Mozambique	4,000	6,100 e	5,981 r	7,781 r	9,100
Senegal	--	663	5,311 r	6,000	9,975
Sierra Leone	120,349 r	114,163 r	126,022 r	143,000 r	168,000
South Africa	70,000	120,000	100,000 e	110,000 e	100,000 e
Sri Lanka	1,590 e	1,749 r	1,808 r	2,000	2,000 e
Turkey[e]	5,000	5,000	5,000	5,000	5,000
Ukraine[e]	162,000	110,000	90,000	100,000	100,000
United States	(8)	(8)	(8)	(8)	(8)
Total	629,000 r	660,000	762,000 r	886,000 r	803,000
Titanium slag:[e, 9]					
Canada	900,000	900,000	700,000	900,000	1,030,000
South Africa	1,170,000	1,030,000	950,000	830,000	643,000
Total	2,070,000	1,930,000	1,650,000	1,730,000	1,670,000

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

[1]Table includes data available through August 28, 2018. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Ilmenite is also produced in Canada and South Africa, but this output is not included here because most of it is duplicative of output reported under "Titanium slag," and the rest is used for purposes other than production of titanium commodities, principally steel furnace flux and heavy aggregate.

[3]Small amounts of titanium minerals were reportedly produced in various countries and (or) localities, but available information was inadequate to make reliable estimates of output levels.

[4]Does not include production of unbeneficiated anatase ore.

[5]Includes rutile to avoid disclosing company proprietary data. Rounded to one significant digit.

[6]Estimate based on import statistics from trading partners (primarily China and Japan).

[7]Includes U.S. production, rounded to one significant digit, of ilmenite, leucoxene, and rutile to avoid disclosing company proprietary data.

[8]Included with ilmenite and leucoxene to avoid disclosing company proprietary data.

[9]Slag was also produced in China, India, Kazakhstan, Norway, Russia, and Vietnam, but this output was not included under "Titanium slag" to avoid duplicative reporting.