



2017 Minerals Yearbook

SILICON [ADVANCE RELEASE]

SILICON

By Emily K. Schnebele

Domestic survey data and tables were prepared by Molly L. Reid, statistical assistant.

Domestic statistics for silicon metal containing less than 99.9% silicon—silicon metal used as feedstocks for chemical, electronic, and metallurgical applications—were aggregated with those of ferrosilicon to avoid disclosing company proprietary data for both material categories. In 2017, total domestic ferrosilicon and silicon metal production was 415,000 metric tons (t) of contained silicon (table 1). This was an 8% increase compared with 2016 production. On the basis of contained silicon, U.S. exports of silicon products increased to 82,000 t in 2017 from 67,000 t in 2016, a 22% increase. U.S. imports increased slightly to 283,000 t in 2017 from 277,000 t in 2016. Total U.S. apparent consumption of silicon materials, on the basis of contained silicon, was 616,000 t in 2017, a slight increase from that in 2016 (fig. 1, table 1). U.S. annual averages of monthly average spot prices also increased in 2017; silicon metal increased by 28%, 75%-grade ferrosilicon increased by 23%, and 50%-grade ferrosilicon increased by 14% compared with the annual average prices in 2016. Combined world production of ferrosilicon and silicon metal decreased by 12% to 8.67 million metric tons (Mt) on a gross-weight basis compared with 9.91 Mt (revised) in 2016 (table 7). China was the leading producer of these silicon materials, providing 61% of the world total.

Silicon is a light chemical element with metallic and nonmetallic characteristics. Silicon is rarely found free in nature; it combines with oxygen and other elements to form silicates, which compose more than 90% of the Earth's crust. Silica (SiO₂) as quartz or quartzite is used to produce silicon ferroalloys for the iron and steel industries and silicon metal for the aluminum and chemical industries. Silicon metal may be further processed into ultra-high-purity semiconductor or solar grades; these contain 99.9% or greater silicon. The U.S. Geological Survey (USGS) does not survey the ultra-high-purity silicon industry for production and related data; the only information in this report about these grades is from foreign trade statistics and published sources. Unless otherwise noted, silicon metal in this report refers to silicon metal containing less than 99.9% silicon.

Production

Silicon Ferroalloys.—Domestic gross production data for silicon ferroalloys were withheld to avoid disclosing company proprietary data; they were combined with U.S. silicon metal production statistics and reported as total silicon materials (tables 1, 2). Ferrosilicon was produced in the United States by two companies—CC Metals and Alloys, LLC and Ferroglobe PLC. Ferroglobe operated in the United States through two subsidiaries—Globe Metallurgical, Inc. (GMI) and Core Metals Group, LLC (table 3).

Silicon Metal.—Production-related statistics for silicon metal were aggregated with domestic silicon ferroalloys to avoid disclosing company proprietary data. Four companies

produced silicon metal in the United States—Dow Corning Alabama (a wholly owned subsidiary of DowDuPont Inc.); GMI; Mississippi Silicon, LLC; and WVA Manufacturing, LLC (a joint venture between Ferroglobe and DowDuPont) (table 3).

Total Silicon Materials.—Data for all silicon materials that were produced in the United States in 2017—ferrosilicon, miscellaneous silicon alloys, and silicon metal—were derived from company responses to voluntary monthly surveys collected by the USGS. The gross-production data in table 2 were obtained from all operations listed in table 3 that were canvassed by means of the USGS “Silicon Alloys” survey. U.S. production reported in the world production table (table 7) reflects net production of total silicon materials; that is, it includes adjustments in inventory owing to in-plant consumption of ferrosilicon and silicon metal to produce magnesium ferrosilicon, miscellaneous alloys, and different grades of silicon metal.

Annual domestic production of total silicon materials (contained silicon) increased in 2017 (415,000 t) compared with 2016 production (384,000 t). There have been fluctuations, but overall domestic apparent consumption has mirrored production trends, exports have remained about the same, and imports of silicon materials have increased significantly over the last 50 years (fig. 1).

Semiconductor- and Solar-Battery-Grade Silicon.—Hemlock Semiconductor Group (HSC) announced plans in October to eliminate 100 jobs at its manufacturing facility in Hemlock, MI. HSC was a leading producer of polycrystalline silicon and other silicon-based products used for manufacturing semiconductors and solar cells (Jordan, 2017; Hemlock Semiconductor Group, undated).

Following a chemical explosion in September at Wacker Chemie AG's (Munich, Germany) polycrystalline silicon production facility in Charleston, TN, production was suspended for the rest of the year. The explosion was attributed to a mechanical failure in the facility's hydrogen recovery building (Thomson Reuters, 2017; Pace, 2018). The plant had a production capacity of more than 20,000 metric tons per year (t/yr) of polycrystalline silicon and cost approximately \$2.5 billion to build (Wacker Chemie AG, 2017, p. 2).

Consumption

Silicon Ferroalloys and Metal.—Most ferrosilicon (including miscellaneous silicon alloys) was used to produce steel (76%) (table 4). The majority of silicon metal consumed in the United States was used to produce chemicals, such as silanes, silicones, and others. Metallurgical-grade silicon carbide can be substituted for ferrosilicon, especially in iron foundries. Data on North American production and U.S. imports of silicon carbide are reported in the Manufactured Abrasives chapter of the 2017 USGS Minerals Yearbook, volume I, Metals and Minerals, and in the quarterly Mineral Industry Surveys.

In 2017, U.S. apparent consumption of silicon materials (ferrosilicon, miscellaneous silicon alloys, and silicon metal) was 616,000 t of contained silicon (table 1). Global apparent consumption of silicon metal was estimated by CRU Bulk Ferroalloys Monitor (2018a, b) to have increased by about 7% to 2.83 Mt in 2017 from 2.64 Mt in 2016. Apparent consumption of ferrosilicon for the first three quarters of 2017 was estimated to have increased by approximately 9% to 4.25 Mt (contained silicon) compared with that of the same period in 2016. China accounted for about 57% of global apparent ferrosilicon consumption during that period.

Prices

Ferrosilicon and silicon metal prices are affected by changes in supply to, and consumption requirements of, the aluminum, chemical, ferrous foundry, and steel industries. The average annual spot prices reported by S&P Global Platts in 2017 were 86.88 cents per pound for 75%-grade ferrosilicon and 116.56 cents per pound for silicon metal; prices were 23% and 28% greater, respectively, than their average prices in 2016 (table 1). The average annual North American transaction price for 50%-grade ferrosilicon, as calculated from CRU Group weekly listings, was 94.47 cents per pound, a 14% increase from that in 2016.

The average monthly spot price for silicon metal was relatively flat during the first quarter of 2017, ranging from 100.13 cents per pound in January to 101.70 cents per pound in March. The average monthly spot price for silicon metal then increased steadily for the remainder of the year with monthly averages of 104.88 cents per pound in April to 139.25 cents per pound in December. The monthly average price for 75%-grade ferrosilicon began the year at 83.00 cents per pound and increased in the second half of 2017; the monthly average spot price was 86.30 cents per pound in August, increased to 102.38 in September, and ended the year at 101.38 in December. Ferrosilicon, 50% grade, was flat for the first 8 months of 2017 with a monthly average spot price of 91.00 cents per pound, increasing to 102.50 cents per pound by yearend.

Foreign Trade

Trade quantities discussed are based on contained weight. Total U.S. ferrosilicon exports increased by 52% to 10,800 t, and their value increased by 24% to \$29.1 million, from those in 2016. However, the average unit value of exported ferrosilicon with greater than 55% silicon content (ferrosilicon trade category of “More than 55% silicon”) decreased by 26% in 2017 and exported ferrosilicon with less than 55% silicon content (ferrosilicon trade category of “Other ferrosilicon”) decreased by 4% compared with 2016 unit values. The two leading destinations, Mexico (3,540 t) and Canada (3,330 t), accounted for 63% of the total United States ferrosilicon exported in 2017 (table 5). Exports of silicon metal increased by 19% to 70,800 t; however, the value decreased slightly to \$1.58 billion from that in 2016. The two leading destinations of United States silicon metal, Japan (24,900 t) and Taiwan (20,200 t), accounted for 64% of United States silicon metal exports in 2017. Shipments of ultra-high-purity silicon containing more than 99.99%

silicon accounted for 94% of total silicon metal exported and 98% of the total value of combined ferrosilicon and silicon metal exports.

U.S. ferrosilicon imports decreased by 6% to 147,000 t; however, the value of those imports increased by 12% to \$275 million compared with that in 2016. The largest decrease by tonnage in ferrosilicon imports was in the “55%–80% silicon, other” trade category of about 10,100 t, which was 8% less than that of 2016. Imports of “Magnesium ferrosilicon” and “55%–80% silicon, more than 3% Ca” also decreased in 2017; the remaining import trade categories increased in 2017 compared with 2016. Imports of “55%–80% silicon, other” accounted for 84% of total ferrosilicon imports and 79% of total ferrosilicon value (table 6). Russia (40%) and Canada (14%) were the leading sources of total ferrosilicon imports.

Silicon metal imports (136,000 t) increased by 11% from those in 2016 and increased by 4% in value to \$395 million from \$379 million in 2016. Silicon metal in the “99.00%–99.99% silicon” trade category accounted for 75% of the total quantity and 61% of the value of all silicon metal imported in 2017. Brazil (36%) was the leading source of total silicon metal imports, followed by Canada (17%) and Australia (14%) (table 6).

World Industry Structure

In 2017, on a gross-weight basis, the leading producers of ferrosilicon and silicon metal, combined, were China (5.3 Mt), Russia (999,000 t), Norway (500,000 t), and the United States (349,000 t, net production). Excluding production by the United States, world production of ferrosilicon, on a gross-weight basis, was estimated to have been 5.92 Mt in 2017 compared with 6.75 Mt (revised) in 2016. The major ferrosilicon producers in 2017 were China (59%), Russia (16%), and Norway (6%); together they accounted for 81% of total world ferrosilicon production (table 7).

World production of silicon metal, excluding that by the United States, was estimated to have been 2.40 Mt in 2017 compared with 2.85 Mt (revised) in 2016 (table 7). China was, by far, the leading producer of silicon metal in the world in 2017 with an estimated 1.80 Mt, 75% of the world total. Other significant producers of silicon metal in 2017 were Norway (6%), Brazil (5%), and France (4%);

World Review

Bhutan.—In July, India implemented a Goods and Service Tax, which was applied to exports from Bhutan to India (Hindu Business Line, The, 2017). Ferroalloy producers in Bhutan were uncertain of the way the tax would affect exports of ferrosilicon to India. Bhutan’s ferrosilicon 2017 exports to India were 32% less than those in 2016 (Ghalley, 2017; UN Comtrade, 2018).

Brazil.—Brazil’s crude steel production was 34.4 Mt in 2017, a 10% increase compared with 2016 production. The startup of Companhia Siderúrgica do Pecém (CSP) steelmill [a joint venture of Posco (Republic of Korea), Dongkuk Steel Mill Co., Ltd. (Republic of Korea), and Vale S.A. (Brazil)], was responsible for almost half of the increase (Vale S.A., 2017; Camargo, 2018). Steel production had decreased during the past few years owing to one of the worst economic recessions that the

country has experienced, which intensified in the final months of 2016 (Metal-Pages, 2016b; Cascione, 2017). Many metals producers sold electricity to the national grid, which was more profitable than producing metal (Metal-Pages, 2016a). Silicon metal production continued to recover as the cost of electricity became more affordable (CRU Bulk Ferroalloys Monitor, 2017).

China.—In 2017, China led the world in ferrosilicon and silicon metal production with a combined estimated total of 5.3 Mt, the lowest combined production for China since 2006 (Corathers and others, 2012). Both silicon metal and ferrosilicon production decreased in 2017 compared to that of 2016, for a combined production decrease of 18% (table 7). Environmental restrictions on ferrosilicon production facilities led to shutdowns and (or) reduced production in Zhongwei, in the Ningxia Autonomous Region. Ningxia was one of the leading ferrosilicon production regions in China, accounting for about 28% of China's total ferrosilicon production capacity (Argus Metals International, 2017a, b).

China's ferrosilicon exports (410,000 t) were almost double those in 2016 (230,000 t); however, they were essentially the same as exports in 2014 (TEX Report, The, 2016, 2018c, d). Ferrosilicon containing more than 55% silicon accounted for the bulk of the ferrosilicon exports at 374,000 t (91%). The leading countries of destination for this ferrosilicon grade were Japan (35%) and the Republic of Korea (20%) (TEX Report, The, 2018a). China's silicon metal exports increased in 2017 by 17% to 837,900 t from 714,700 t in 2016. The leading countries of destination for silicon metal from China were Japan (23%) and the Republic of Korea (18%) (TEX Report, The, 2018b).

Macedonia.—Production at the sole ferrosilicon producer Jugohrom Ferroalloys Ltd. remained suspended. The plant had been forced to shut down in November 2016 when it failed to install Government-required pollution reduction systems. Operations were expected to resume in mid-2018, following the installation of required dust collection filters (Central European Financial Observer, 2017). The particulate matter in the air around the plant had been 8 times higher than World Health Organization (WHO) standards and in the winter increased to more than 10 times higher than WHO standards (Mikhaylova, 2016).

Malaysia.—OM Materials Sarawak SDN BHD, the only ferrosilicon producer in Malaysia, increased production to 175,000 t in 2017 compared with 126,000 t in 2016. At yearend, OM Sarawak had nine furnaces producing ferrosilicon (OM Holdings Ltd., 2018).

Russia.—Russia exported 318,000 t of ferrosilicon in 2017, 29% less than the 447,000 t exported in 2016. Ferrosilicon, greater than 55% silicon grade, exported to Japan represented 29% of the total amount of ferrosilicon exported by Russia in 2017. Russia imported 17,000 t of ferrosilicon, 18% more than the 14,400 t imported in 2016. Russia exported 15,700 t of silicon metal and imported 16,300 t of silicon metal in 2017, 20% less and 24% greater, respectively, than that of 2016. Silicon metal, "containing by weight less than 99.99% of silicon," accounted for more than 90% all silicon metal exported from or imported to Russia in 2017 (UN Comtrade, 2018).

South Africa.—Silicon Smelters (Pty) Ltd. (a wholly owned subsidiary of Ferroglobe) idled two of the three furnaces at its silicon metal plant in Polokwane and reduced production at its

eMalahleni ferrosilicon and foundry production plant (Argus Metals International, 2017c). Operations were suspended owing to high electricity prices (Argus Metals International, 2017d). Ferroglobe's silicon metal sales in South Africa decreased by almost 64% compared with those of 2016 owing to the idled furnaces at Polokwane (Ferroglobe PLC, 2018, p. 73). Ferroglobe reached an agreement with Eskom Holdings SOC Ltd., an electricity supplier in South Africa, and approval from the country's National Energy Regulator, whereby three furnaces at Polokwane and one furnace at eMalahleni were offered a 2-year discount on the electricity consumed to produce silicon. The aim of the agreement was to promote the production of silicon in South Africa (Ferroglobe PLC, 2018, p. 129).

Spain.—Ferroglobe converted a furnace at its Sabón facility from silicon metal to ferrosilicon production during the first quarter of 2017. The converted 20,000 t/yr furnace was switched in anticipation of increased ferrosilicon demand following increased steel production (Conway, 2017). The conversion led to a decrease in estimated silicon metal production in 2017 (7,500 t) compared with 2016 (30,000 t) (table 7).

Venezuela.—FerroAtlántica de Venezuela, S.A. (FerroVen) (a wholly owned subsidiary of Ferroglobe), the sole ferrosilicon producer in Venezuela, was idled in 2016 owing to market conditions. Ferroglobe determined that the costs to dispose of the FerroVen assets exceeded their fair value, owing primarily to political and financial instability in Venezuela. The company wrote off the value of the property, plant, and equipment of FerroVen (Ferroglobe PLC, 2018, p. 67).

Outlook

Domestic and global consumption of ferrosilicon are expected to closely follow the trend in steel production. Details of the outlook for the steel industry are discussed in the "Outlook" section of the Iron and Steel chapter of the 2017 USGS Minerals Yearbook, volume I, Metals and Minerals.

Global crude steel production in 2017 was 1.69 billion metric tons (Gt), compared with 1.63 Gt in 2016. China, the world's leading producer of raw steel, produced 831.7 Mt in 2017, a 3% increase from the 807.6 Mt produced in 2016. U.S. crude steel production in 2017 was 81.6 Mt, a 4% increase compared with the 78.5 Mt produced in 2016. World apparent consumption of finished steel products increased by 5% to 1.59 Gt in 2017. China, the leading world consumer of steel products, increased consumption by 8% to 737 Mt in 2017 from 680 Mt in 2016. The combined steel consumption in China, India, Japan, the Republic of Korea, and the United States increased by 7% to 1,043 Mt from 975 Mt; these five countries accounted for about 66% of the world total in 2017 (World Steel Association, 2018a, p. 7, 9, 16). The World Steel Association's short-range forecast for global steel demand is 1.62 Gt in 2018 and 1.63 Gt in 2019 (World Steel Association, 2018b).

Silicon metal is consumed primarily in the aluminum and chemical industries. Ferroglobe (2016, p. 27–29) estimated world silicon metal consumption to be divided between the silicone (50%), aluminum (40%), and solar (10%) markets. Global consumption of silicones was forecast to increase by 5.1% annually through 2021 (Freedonia Group, Inc., The, 2017).

Consumption of silicon metal by the U.S. aluminum castings industry is expected to mirror the short-term 2.5% annual growth from 2017 to 2020 and long-term annual growth rate of 4% from 2017 to 2026 in domestic aluminum casting sales (Modern Casting, 2018, p. 25).

Global consumption of polycrystalline silicon was forecast to increase by a compound average growth rate of 10.2% from 2016 to 2025 (Grand View Research, 2016). Consumption of polycrystalline silicon is predominantly for solar-grade and semiconductor end uses.

References Cited

- Argus Metals International, 2017a, China's Boyuan Silicon switches to FeSi output: Argus Media group, Argus Metals International, December 13. (Accessed June 19, 2018, via <http://www.argusmedia.com/metals/>.)
- Argus Metals International, 2017b, Environmental regulations reduce Chinese FeSi supply: Argus Media group, Argus Metals International, December 4. (Accessed January 8, 2018, via <http://www.argusmedia.com/metals/>.)
- Argus Metals International, 2017c, Ferroglobe lifts ferro-alloy, Si metal output: Argus Media group, Argus Metals International, November 28. (Accessed January 8, 2018, via <http://www.argusmedia.com/metals/>.)
- Argus Metals International, 2017d, South Africa alloy producers seek power deal: Argus Media group, Argus Metals International, December 7. (Accessed January 12, 2018, via <http://www.argusmedia.com/metals/>.)
- Camargo, A.P., 2018, Brazil's crude steel output up 10% in 2017—Sales rise 2.3% on flat steel performance: Metal Bulletin, January 22. (Accessed July 13, 2018, via <https://www.metalbulletin.com>.)
- Cascione, Silvio, 2017, Brazil's worst-ever recession unexpectedly deepens in late 2016: Reuters, March 7. (Accessed July 25, 2017, at <http://www.reuters.com/article/us-brazil-economy-gdp-idUSKBN16E1EL>.)
- Central European Financial Observer, 2017, Macedonian Jugohrom Ferroalloys plant to resume work in May or June 2018: Central European Financial Observer [Swietokrzyska, Poland], October 13. (Accessed July 17, 2018, at <https://financialobserver.eu/recent-news/macedonian-jugohrom-ferroalloys-plant-to-resume-work-in-may-or-june-2018/>.)
- Conway, Declan, 2017, Ferroglobe increases ferrosilicon production at Sabón facility: American Metal Market, May 31. (Accessed July 7, 2017, via <http://www.amm.com/>.)
- Corathers, L.A., Gambogi, J., Kuck, P.H., Papp, J.F., Polyak, D.E., and Shedd, K.B., 2012, Ferroalloys, in *Metals and Minerals: U.S. Geological Survey Minerals Yearbook 2010*, v. I, p. 25.1–25.16. (Also available at <https://minerals.usgs.gov/minerals/pubs/commodity/ferroalloys/myb1-2010-feall.pdf>.)
- CRU Bulk Ferroalloys Monitor, 2017, Silicon metal prices rise further in the USA: CRU Bulk Ferroalloys Monitor, December 7. (Accessed July 16, 2018, via <https://cruonline.crugroup.com/>.)
- CRU Bulk Ferroalloys Monitor, 2018a, Ferrosilicon—Ferrosilicon supply/demand balance: CRU Bulk Ferroalloys Monitor, July. (Accessed July 16, 2018, via <https://www.crugroup.com/analysis/ferroalloys/>.)
- CRU Bulk Ferroalloys Monitor, 2018b, Silicon metal—Silicon metal supply/demand balance: CRU Bulk Ferroalloys Monitor, July. (Accessed July 16, 2018, via <https://www.crugroup.com/analysis/ferroalloys/>.)
- Ferroglobe PLC, 2016, Ferroglobe—Investor presentation: London, United Kingdom, Ferroglobe PLC, May 9, 35 p. (Accessed July 23, 2018, at http://files.shareholder.com/downloads/AMDA-5STP82/4530844666x0x925388/06493FD0-3C33-49AE-A17E-63A4ED53FEB3/Ferroglobe_MayInvestor_Presentation.pdf.)
- Ferroglobe PLC, 2018, Form 20-F—2016: U.S. Securities and Exchange Commission, 412 p.
- Freedonia Group, Inc., The, 2017, Global silicones market—Demand and sales forecasts, market share, market size, market leaders: Cleveland, OH, The Freedonia Group study #3531 brochure, June, 221 p. (Accessed July 23, 2018, at <https://www.freedoniagroup.com/World-Silicones.html>.)
- Ghalley, Krishna, 2017, Ferrosilicon industries in the dark about GST impact: Business [Changzamtok, Thimphu] Bhutan, July 8. (Accessed July 17, 2018, at <http://www.businessbhutan.bt/businessbhutan/ferrosilicon-industries-in-the-dark-about-gst-impact/>.)
- Grand View Research, 2016, Polysilicon market analysis by application (photovoltaic, electronics), by region (North America, Europe, Asia Pacific, Central & South America, Middle East & Africa), trends & dynamics, competitive landscape, and segment forecasts, 2018–2025: San Francisco, CA, Grand View Research, December. (Accessed July 23, 2018, at <http://www.grandviewresearch.com/industry-analysis/polysilicon-market-analysis>.)
- Hemlock Semiconductor Group, [undated], Facts & figures—Focusing on people, processes, and plants to meet your needs: Hemlock, MI, Hemlock Semiconductor Group. (Accessed July 17, 2018, at http://www.hscpoly.com/content/hsc_comp/facts_figures.aspx.)
- Hindu Business Line, The, 2017, Bhutanese economy likely to be impacted by GST—ADB: The Hindu Business Line [Chennai (Madras), India], October 1. (Accessed July 16, 2018, at <https://www.thehindubusinessline.com/news/world/bhutanese-economy-likely-to-be-impacted-by-gst-adb/article9883186.ece>.)
- Jordan, Heather, 2017, Hemlock Semiconductor to cut 100 jobs: Saginaw [MI] News, October 18. (Accessed July 17, 2018, at https://www.mlive.com/news/saginaw/index.ssf/2017/10/hemlock_semiconductor_to_cut_1.html.)
- Metal-Pages, 2016a, Europe light metals—Profit taking weighs on prices: Argus Media group Metal-Pages, December 20. (Accessed July 3, 2017, via <http://www.argusmedia.com/metals/>.)
- Metal-Pages, 2016b, Ferbasa ferro-alloys output falls in October: Argus Media group Metal-Pages, November 22. (Accessed July 3, 2017, via <http://www.argusmedia.com/metals/>.)
- Mikhaylova, Marina, 2016, Macedonia's Jugohrom Ferroalloys to halt work over air pollution—Report: SeeNews—Business Intelligence for Southeast Europe [Sofia, Bulgaria], November 2. (Accessed July 17, 2018, at <https://seeneews.com/news/macedonias-jugohrom-ferroalloys-to-halt-work-over-air-pollution-report-545362>.)
- Modern Casting, 2018, 2018 forecast—U.S. casting sales to reach \$33 billion: Lansing, MI, Modern Casting, January, p. 22–27. (Accessed July 23, 2018, at <http://content.digitalpub.blue-soho.com/web/y5b2/0A1snzj/ModernCastingJan2018/html/index.html?page=26&origin=reader>.)
- OM Holdings Ltd., 2018, Appendix 4E—Preliminary final report for the year ended 31 December, 2017: Singapore, Malaysia, OM Holdings Ltd., February 22. (Accessed July 16, 2018, via http://www.omholdingsltd.com/ir_report.htm.)
- Pace, Mark, 2018, Wacker to resume chemical operations nearly 8 months after explosion: Times Free Press [Chattanooga, TN], April 26. (Accessed July 17, 2018, at <https://www.timesfreepress.com/news/breakingnews/story/2018/apr/26/wacker-resume-chemical-operations-more-8-months-after-explosion/469318/>.)
- TEX Report, The, 2016, China's import and export results of ferroalloys in December 2015: The TEX Report, v. 48, no. 11349, February 4, p. 9.
- TEX Report, The, 2018a, China's export of ferro-silicon in December 2017 is 41,529 tons: The TEX Report, v. 50, no. 11836, February 7, p. 20.
- TEX Report, The, 2018b, China's export of silicon metal in December 2017 is 90,467 tons: The TEX Report, v. 50, no. 11839, February 13, p. 17.
- TEX Report, The, 2018c, China's import and export results of ferroalloys in January 2018: The TEX Report, v. 50, no. 11852, March 2, p. 18.
- TEX Report, The, 2018d, China's import and export results of ferroalloys in November 2017: The TEX Report, v. 50, no. 11814, January 5, p. 18.
- Thomson Reuters, 2017, Wacker Chemie expects U.S. polysilicon plant to be out of action for months: London, United Kingdom, Thomson Reuters, September 20. (Accessed July 17, 2018, at <https://www.reuters.com/article/us-wacker-chemie-usa/wacker-chemie-expects-u-s-polysilicon-plant-to-be-out-of-action-for-months-idUSKCN1BV24P>.)
- UN Comtrade, 2018, UN comtrade database: Geneva, Switzerland, United Nations. (Accessed July 10, 2018, via <http://comtrade.un.org/>.)
- Vale S.A., 2017, Vale's CEO participates in the celebration of Companhia Siderúrgica do Pecém, in Ceara: Rio de Janeiro, Brazil, Vale S.A. press release, April 4. (Accessed July 13, 2018, at <http://www.vale.com/brasil/PT/aboutvale/news/Paginas/diretor-presidente-vale-participa-inauguracao-companhia-siderurgica-pecem-ceara.aspx>.)
- Wacker Chemie AG, 2017, Annual report 2016: Adrian, MI, Wacker Chemie AG, 200 p. (Accessed August 3, 2017, at https://www.wacker.com/cms/media/en/documents/wacker_group/annual_report_16.pdf.)
- World Steel Association, 2018a, World steel in figures 2018: Brussels, Belgium, World Steel Association, 17 p. (Accessed July 9, 2018, at <https://www.worldsteel.org/en/dam/jcr:f9359dff-9546-4d6b-bed0-996201185b12/World+Steel+in+Figures+2018.pdf>.)

World Steel Association, 2018b, Worldsteel short range outlook April 2018: Brussels, Belgium, World Steel Association, April 17. (Accessed July 9, 2018, at <https://www.worldsteel.org/media-centre/press-releases/2018/worldsteel-short-range-outlook-april-2018.html>.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.

Silicon. Ch. in Mineral Commodity Summaries, annual.

Silicon. Mineral Industry Surveys, monthly.
Silicon (Si). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.

Other

Company news releases and reports.

CRU Group.

S&P Global Platts.

Silicon. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT SILICON STATISTICS¹

(Contained silicon, unless otherwise noted)

	2013	2014	2015	2016	2017	
United States:						
Production:						
Ferrosilicon	thousand metric tons	W	W	W	W	W
Silicon metal ²	do.	W	W	W	W	W
Total silicon materials ³	do.	392	401	411	384	415
Exports:						
Ferrosilicon	do.	10	9	9	7	11
Silicon metal	do.	38	45	37	60	71
Imports for consumption:						
Ferrosilicon	do.	157	186	162	155	147
Silicon metal	do.	118	139	140	122	136
Apparent consumption:						
Ferrosilicon	do.	W	W	W	W	W
Silicon metal ²	do.	W	W	W	W	W
Total silicon materials ³	do.	631	670	661	601	616
Price, average:						
Ferrosilicon, 50% Si ⁴	cents per pound	102.56	107.81	101.19	82.70	94.47
Ferrosilicon, 75% Si ⁵	do.	94.27	98.35	88.11	70.76	86.88
Silicon metal ⁵	do.	122.39	140.39	126.63	91.14	116.56
World production, gross weight:						
Ferrosilicon ⁶	thousand metric tons	8,520	7,990 ^r	7,330 ^r	6,750 ^r	5,920
Silicon metal ⁷	do.	2,060	2,320	2,540 ^r	2,850 ^r	2,400
Total silicon materials ^{3, 8}	do.	10,900	10,700	10,200	9,910 ^r	8,670

^rRevised. do. Ditto. W Withheld to avoid disclosing company proprietary data.

¹Table includes data available through August 16, 2018. Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

²Does not include semiconductor and solar grades of silicon metals.

³Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal, excluding semiconductor and solar grades.

⁴CRU Group transaction prices based on weekly averages.

⁵S&P Global Platts mean import prices based on monthly averages.

⁶Does not include net production of ferrosilicon in the United States.

⁷Does not include net production of silicon metal in the United States.

⁸Includes total net production of ferrosilicon and silicon metal in the United States.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF SILICON
ALLOYS AND METAL IN THE UNITED STATES^{1,2}

(Metric tons, gross weight)

	Gross production ³	Net shipments	Producers' stocks, December 31
2016:			
Ferrosilicon	W	W	W
Silicon metal	W	W	W
Total silicon materials	471,000	318,000	37,100
2017:			
Ferrosilicon	W	W	W
Silicon metal	W	W	W
Total silicon materials	518,000	352,000	33,500

W Withheld to avoid disclosing company proprietary data.

¹Table includes data available through August 16, 2018. Data are rounded to no more than three significant digits.

²Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal, excluding semiconductor and solar grades, unless otherwise noted.

³Ferrosilicon production includes material consumed in the production of miscellaneous silicon alloys.

TABLE 3
PRINCIPAL PRODUCERS OF SILICON ALLOYS AND (OR) SILICON
METAL IN THE UNITED STATES IN 2017¹

Producer	Plant location	Product
CC Metals and Alloys, LLC	Calvert City, KY	Ferrosilicon.
Dow Corning Alabama ²	Mt. Meigs, AL	Silicon metal.
Globe Metallurgical, Inc. ³	Beverly, OH	Ferrosilicon and silicon metal.
Do.	Niagara Falls, NY	Silicon metal.
Do.	Selma, AL	Do.
Mississippi Silicon, LLC ⁴	Burnsville, MS	Do.
Core Metals Group, LLC ³	Bridgeport, AL	Ferrosilicon.
WVA Manufacturing, LLC ⁵	Alloy, WV	Silicon metal.
Do. Ditto.		

¹Silicon metal producers do not include semiconductor and solar-grade silicon manufacturers.

²A wholly owned subsidiary of DowDuPont Inc.

³A wholly owned subsidiary of Ferroglobe PLC.

⁴Owned by Rima Industrial S.A. and CleanTech, LLC.

⁵A joint venture between Ferroglobe PLC and DowDuPont Inc.

TABLE 4
 REPORTED CONSUMPTION, BY END USE, AND STOCKS OF SILICON FERROALLOYS AND METAL IN THE
 UNITED STATES IN 2017^{1,2}

(Metric tons, gross weight)

End use	Silvery pig iron ³	Ferrosilicon, 50% ⁴	Ferrosilicon, 75% ⁵	Silicon metal ⁶	Miscellaneous silicon alloys ⁷	Silicon carbide ⁸
Steel:						
Carbon and high-strength, low-alloy	21	(9)	34,100	(9)	(9)	W
Stainless and heat-resisting	--	(9)	44,300	(9)	(9)	W
Full alloy	--	(9)	8,710	(9)	(9)	--
Electric steel	--	--	(9)	--	--	W
Electric and tool	--	--	(9)	--	--	--
Unspecified	--	47,800	32,900	1,590	902	--
Total	21	47,800	120,000	1,590	902	W
Cast irons	W	17,900	21,300	(10)	12,700	18,300
Superalloys	--	--	(11)	61	--	--
Welding	--	(12)	--	(10)	--	--
Wear and corrosion	--	(12)	(11)	(10)	(12)	--
Aluminum	--	--	(11)	(10)	--	(12)
Copper	--	--	--	(10)	--	--
Nickel	--	--	(11)	(10)	(12)	--
Tungsten	--	--	--	(10)	--	--
Other alloy	--	(12)	--	--	(12)	--
Chemical carbides	--	--	--	--	(12)	--
Alloys, excluding superalloys and alloy steel	--	--	--	24,900 ¹³	--	--
Miscellaneous and unspecified	--	--	272	W ¹⁴	(12)	--
Grand total	W	65,800	141,000	W	13,600	W
Consumers' stocks, December 31	387	807	9,060	12,800	410	967

W Withheld to avoid disclosing company proprietary data. -- Zero.

¹Table includes data available through August 16, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes U.S. Geological Survey estimates.

³Typically 18% silicon content but ranges between 5% and 24% silicon content.

⁴Typically 48% silicon content but ranges between 25% and 55% silicon content; includes briquets.

⁵Typically 76% silicon content but ranges between 56% and 95% silicon content; includes briquets.

⁶Typically 98% silicon content but ranges between 96% and 99% silicon content.

⁷Typically 48% silicon content. Primarily magnesium-ferrosilicon but also includes other silicon alloys.

⁸Typically 64% silicon content but ranges between 63% and 70% silicon content. Does not include silicon carbide for abrasive or refractory uses.

⁹Included with "Steel: Unspecified," to avoid disclosing company proprietary data.

¹⁰Included with "Alloys, excluding superalloys and alloy steel" to avoid disclosing company proprietary data.

¹¹Included with "Miscellaneous and unspecified," to avoid disclosing company proprietary data.

¹²Included with "Cast irons," to avoid disclosing company proprietary data.

¹³Primarily aluminum alloys.

¹⁴Primarily silicones and other chemicals.

TABLE 5
U.S. EXPORTS OF FERROSILICON AND SILICON METAL IN 2017^{1,2}

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
Ferrosilicon:			
More than 55% silicon:			
Belgium	293	162	\$133,000
Brazil	72	43	148,000
Canada	4,540	2,730	6,500,000
India	172	103	214,000
Japan	20	12	33,200
Mexico	2,910	1,740	6,020,000
Netherlands	2,740	1,710	2,220,000
South Africa	237	142	104,000
Turkey	12	7	18,500
United Kingdom	80	56	49,100
Other [3 countries and (or) localities]	23	14	50,400
Total	11,100	6,720	15,500,000
Other ferrosilicon:			
Belgium	867	390	877,000
Brazil	471	230	836,000
Canada	1,210	605	600,000
France	320	142	522,000
Indonesia	122	52	185,000
Korea, Republic of	566	250	621,000
Mexico	3,910	1,800	7,580,000
Thailand	120	50	220,000
Turkey	164	82	246,000
United Kingdom	804	366	1,270,000
Other [7 countries and (or) localities]	310	151	664,000
Total	8,870	4,120	13,600,000
Total ferrosilicon	20,000	10,800	29,100,000
Metal:			
More than 99.99% silicon:			
China	5,110	5,110	64,300,000
Germany	2,780	2,780	73,100,000
Hong Kong	2,970	2,970	27,400,000
Japan	24,800	24,800	807,000,000
Korea, Republic of	5,570	5,570	199,000,000
Malaysia	660	660	38,500,000
Norway	643	643	5,270,000
Philippines	1,680	1,680	60,400,000
Singapore	1,130	1,130	27,200,000
Taiwan	20,200	20,200	255,000,000
Other [43 countries and (or) localities]	844	844	18,800,000
Total	66,400	66,400	1,580,000,000
99.00–99.99% silicon:			
Belgium	79	79	85,500
China	203	203	206,000
Germany	15	15	21,600
Israel	26	26	37,200
Japan	12	12	17,000
Mexico	22	21	52,600
Netherlands	877	869	1,120,000
Peru	71	71	88,600
Thailand	15	15	21,700
United Kingdom	643	638	728,000
Other [7 countries and (or) localities]	30	29	55,600
Total	1,990	1,980	2,430,000

See footnotes at end of table.

TABLE 5—Continued
 U.S. EXPORTS OF FERROSILICON AND SILICON METAL IN 2017^{1,2}

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
Metal:—Continued			
Other silicon:			
Belgium	697	680	798,000
Canada	495	481	1,210,000
China	268	261	359,000
Germany	54	53	\$90,200
Japan	24	23	234,000
Korea, Republic of	28	27	58,600
Mexico	380	369	1,110,000
Netherlands	157	154	119,000
South Africa	88	86	171,000
United Kingdom	211	205	481,000
Other [11 countries and (or) localities]	75	73	334,000
Total	2,480	2,410	4,970,000
Total silicon metal	70,900	70,800	1,580,000,000

¹Table includes data available through August 16, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Countries listed are the leading importers in terms of quantity (gross weight).

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL
IN 2017^{1,2}

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
Ferrosilicon:			
55%–80% silicon, more than 3% Ca:			
Argentina	96	74	\$195,000
Brazil	3,950	2,850	5,660,000
China	725	544	789,000
France	608	366	1,650,000
Germany	2	1	6,070
South Africa	303	211	603,000
Total	5,690	4,040	8,900,000
55%–80% silicon, other:			
Brazil	5,930	4,450	6,890,000
Canada	12,200	8,870	26,500,000
China	14,900	11,200	16,800,000
France	1,730	1,180	4,750,000
Iceland	18,100	14,100	20,400,000
Kazakhstan	20,200	15,400	24,900,000
Malaysia	5,160	3,820	5,490,000
Norway	1,010	763	1,120,000
Russia	77,200	59,100	97,900,000
South Africa	1,960	1,350	4,730,000
Other [13 countries and (or) localities]	3,980	2,920	8,430,000
Total	162,000	123,000	218,000,000
80%–90% silicon:			
Bosnia and Herzegovina	371	317	609,000
Germany	123	102	161,000
Total	494	419	770,000
More than 90% silicon:			
Brazil	4,620	4,280	2,360,000
China	52	47	15,800
France	140	129	42,700
Total	4,820	4,450	2,420,000
Magnesium ferrosilicon:			
Argentina	655	230	736,000
Canada	12,600	5,740	22,200,000
China	286	133	389,000
France	10	5	42,500
Germany	101	41	271,000
India	2,180	672	2,740,000
Norway	137	65	239,000
Total	16,000	6,890	26,700,000
Other ferrosilicon:			
Canada	15,200	5,290	13,500,000
China	12,000	2,120	4,040,000
France	12	6	43,400
Germany	55	21	199,000
India	74	33	79,900
Japan	13	6	21,900
Russia	150	73	236,000
Slovakia	199	49	254,000
South Africa	11	5	15,500
Trinidad and Tobago	89	14	34,800
Other [2 countries and (or) localities]	5	2	9,020
Total	27,800	7,620	18,400,000
Total ferrosilicon	217,000	147,000	275,000,000

See footnotes at end of table.

TABLE 6—Continued
 U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL
 IN 2017^{1,2}

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
Metal:			
More than 99.99% silicon:			
Brazil	9,170	9,170	22,000,000
China	78	78	9,750,000
Denmark	4	4	1,890,000
Germany	819	819	45,600,000
Japan	232	232	10,900,000
Norway	96	96	602,000
Singapore	7	7	51,100
Spain	3	3	25,600
Taiwan	532	532	16,200,000
Ukraine	3	3	253,000
Other [9 countries and (or) localities]	5	5	645,000
Total	10,900	10,900	108,000,000
99.00%–99.99% silicon:			
Australia	17,500	17,300	37,400,000
Bosnia and Herzegovina	6,480	6,430	14,200,000
Brazil	31,100	30,800	78,500,000
Canada	21,900	21,700	57,700,000
France	626	620	985,000
Kazakhstan	7,960	7,900	14,400,000
Laos	519	516	1,180,000
Norway	6,530	6,490	14,700,000
South Africa	975	966	2,070,000
Thailand	7,450	7,400	16,700,000
Other [7 countries and (or) localities]	788	781	1,530,000
Total	102,000	101,000	239,000,000
Other silicon:			
Australia	1,560	1,520	3,030,000
Brazil	9,070	8,910	21,200,000
Canada	1,130	1,110	2,650,000
France	385	373	679,000
Iceland	974	957	1,640,000
Japan	401	385	567,000
Kazakhstan	1,240	1,210	2,100,000
Norway	7,560	7,380	13,100,000
South Africa	522	508	847,000
Thailand	394	382	864,000
Other [9 countries and (or) localities]	879	855	1,670,000
Total	24,100	23,600	48,300,000
Total silicon metal	137,000	136,000	395,000,000

¹Table includes data available through August 16, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Countries listed are the leading importers in terms of quantity (gross weight).

Source: U.S. Census Bureau.

TABLE 7
FERROSILICON AND SILICON METAL: WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons, gross weight)

Country or locality ³	2013	2014	2015	2016	2017
Argentina, ferrosilicon ^e	15,000	17,000	12,700	12,000	13,000
Australia, silicon metal ^c	30,000	48,000	48,000	48,000	50,000
Bhutan, ferrosilicon ⁴	82,992	79,485	104,406	106,234 ^r	84,593
Bosnia and Herzegovina, silicon metal	16,707	18,383	18,716	28,138 ^r	28,100 ^c
Brazil: ^c					
Ferrosilicon	147,000	98,000	88,300	62,300	88,000
Silicon metal	134,000	92,300	70,000	130,000 ^r	115,000
Canada:					
Ferrosilicon	38,871	32,000 ^c	38,000 ^c	38,000 ^c	40,000 ^c
Silicon metal ^c	12,000	30,000	30,000	27,000	28,300
China: ^c					
Ferrosilicon ^c	5,940,000	5,500,000	4,730,000	4,300,000	3,500,000
Silicon metal ^c	1,450,000	1,710,000	1,950,000	2,200,000	1,800,000
Egypt, ferrosilicon ⁵	50,800 ^c	56,794	56,093	60,477 ^r	60,500 ^c
France: ^c					
Ferrosilicon	50,000	50,000	35,000	35,000	35,000
Silicon metal	100,000	100,000	100,000	100,000	105,000
Germany, silicon metal ^c	28,000	28,000	30,000	30,000	30,000
Iceland, ferrosilicon	125,204	112,657 ^r	121,556	128,019 ^r	116,811
India, ferrosilicon ⁵	92,013	92,014	92,000	90,000	90,000
Kazakhstan:					
Ferrosilicon	472	395	86,984	68,779 ^r	59,926
Silicon metal	5,000 ^c	998	866	--	--
Laos, silicon metal ⁶	12,472	9,503	5,673	6,836 ^r	1,042
Macedonia, ferrosilicon	72,279	73,014	45,698	24,400 ^{r,c}	21
Malaysia, ferrosilicon	--	8,640 ^c	46,832	126,261	174,540
Norway:					
Ferrosilicon	349,389	350,000 ^c	350,000 ^c	350,000 ^c	350,000 ^c
Silicon metal	150,000	150,000 ^c	150,000 ^c	150,000 ^c	150,000 ^c
Poland, ferrosilicon	73,589	62,878	77,754 ^r	77,682 ^r	78,000 ^c
Russia:					
Ferrosilicon	1,012,740	1,026,190	1,057,909 ^r	935,912 ^r	940,000 ^c
Silicon metal	55,000 ^c	60,000 ^c	60,000 ^c	59,300	59,300 ^c
Slovakia, ferrosilicon	41,664	47,019	45,961	38,030 ^r	38,000 ^c
South Africa:					
Ferrosilicon	78,400	87,700	91,000 ^{r,c}	71,200 ^c	60,000 ^c
Silicon metal	34,100	47,200	47,000 ^{r,c}	39,100 ^c	26,500 ^c
Spain: ^c					
Ferrosilicon	80,500	80,500	80,000	80,000	95,000
Silicon metal	29,200	29,200	24,000 ^r	30,000	7,500
Turkey, ferrosilicon ⁷	1,900 ^r	3,400 ^r	1,400 ^r	2,600 ^r	2,700
Ukraine, ferrosilicon	191,207	142,300 ^r	90,200 ^r	101,420 ^r	92,910
United States:					
Ferrosilicon	W	W	W	W	W
Silicon metal	W	W	W	W	W
Total, silicon materials ⁸	337,000	361,000	325,000	310,000	349,000
Uzbekistan, silicon metal ^c	6,000	5,000	5,000	3,000	3,000
Venezuela, ferrosilicon ^c	74,300	74,300	74,300	37,000	--
Grand total	10,900,000	10,700,000	10,200,000	9,910,000 ^r	8,670,000
Of which:					
Ferrosilicon ⁹	8,520,000	7,990,000 ^r	7,330,000 ^r	6,750,000 ^r	5,920,000
Silicon metal ¹⁰	2,060,000	2,320,000	2,540,000 ^r	2,850,000 ^r	2,400,000
U.S. total, silicon materials ⁸	337,000	361,000	325,000	310,000	349,000

See footnotes at end of table.

TABLE 7—Continued
 FERROSILICON AND SILICON METAL: WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons, gross weight)

⁶Estimated. ⁷Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

¹Table includes data available through July 19, 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.

²Does not include semiconductor and solar grades of silicon metal.

³In addition to the countries and (or) localities listed, Iran and Uruguay may have produced ferrosilicon and Thailand may have produced silicon metal, but available information was inadequate to make reliable estimates of output.

⁴Total of imports received by all countries from Bhutan. Source: UN Comtrade.

⁵Reported on a fiscal year basis, with start dates as follows: Egypt, July 1, and India, April 1.

⁶Total of imports received by all countries from Laos. Source: UN Comtrade.

⁷Exports. Source: UN Comtrade.

⁸Includes total U.S. net production of ferrosilicon and silicon metal.

⁹Does not include total U.S. net production of ferrosilicon.

¹⁰Does not include total U.S. net production of silicon metal.

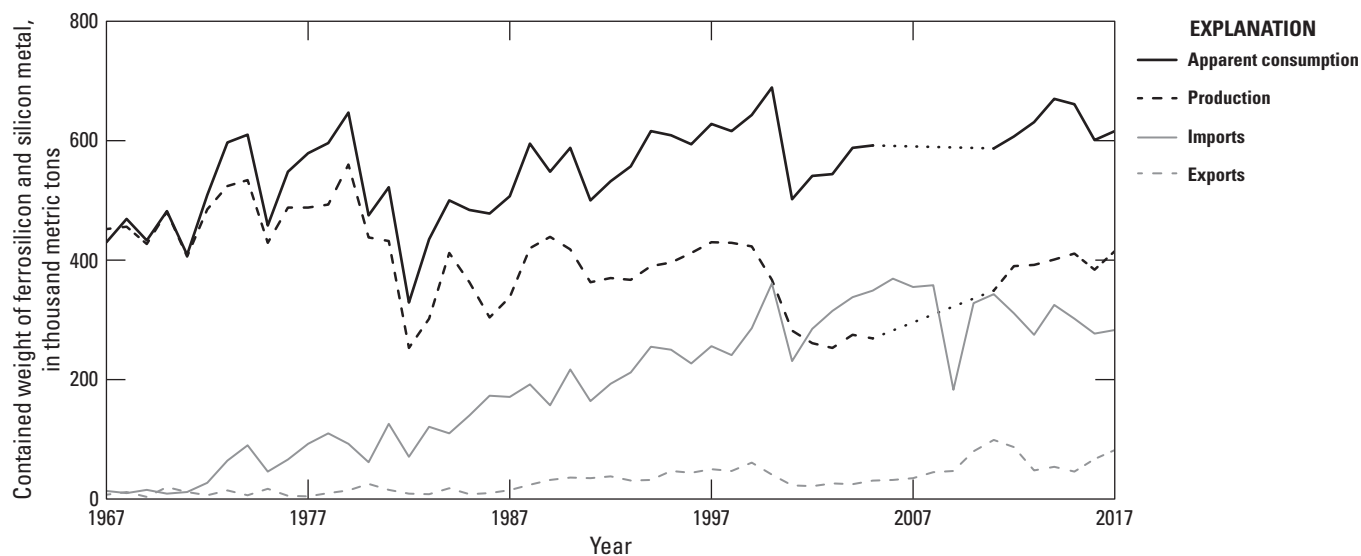


Figure 1. Gross domestic production, U.S. imports and exports, and domestic apparent consumption of ferrosilicon and silicon metal (contained silicon) from 1967 through 2017. Silicon metal refers to silicon metal containing less than 99.9% silicon. Data for silicon metal production and apparent consumption were withheld from publication from 2006 through 2010 to avoid disclosing propriety data; these data were interpolated for this graph and are represented by dotted lines. Sources: U.S. Bureau of Mines, U.S. Census Bureau, and U.S. Geological Survey.