



2015 Minerals Yearbook

SILICON [ADVANCE RELEASE]

SILICON

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Domestic statistics for silicon metal containing less than 99.9% silicon—silicon metal used as feedstock for chemical, electronic, and metallurgical applications—were aggregated with those of ferrosilicon to avoid disclosing company proprietary data for both material categories. In 2015, total gross domestic ferrosilicon and silicon metal production was 411,000 metric tons (t) of contained silicon (table 1). This was a slight increase compared with 2014 production. On the basis of contained silicon, U.S. exports of silicon products decreased by 15% and imports decreased by 7%. Total U.S. apparent consumption of silicon materials was 661,000 t in 2015, which was a slight decrease from that in 2014 (revised) (fig. 1, table 1). U.S. monthly average spot prices also decreased in 2015; both silicon metal and 75%-grade ferrosilicon decreased by 10%; 50%-grade ferrosilicon decreased by 6% compared with monthly average prices in 2014. Combined world production of ferrosilicon and silicon metal decreased by 5% to 10.1 million metric tons (Mt) on a gross-weight basis compared with a revised 10.7 Mt in 2014 (table 7). China was the leading producer of these silicon materials, providing 66% 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 (SiO_2) 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 Globe Metallurgical, Inc. (GMI), a wholly owned subsidiary of Globe Specialty Metals, Inc. (GSM) (table 3). At yearend, GSM and Spain's Grupo FerroAtlántica finalized their merger, creating the new company, Ferroglobe PLC (Ferroglobe PLC, 2015).

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 Corp.; GMI;

Mississippi Silicon, LLC; and WVA Manufacturing, LLC (table 3). Dow Corning's silicon metal production was used internally to manufacture silicones and other chemicals. In September, Mississippi Silicon, LLC, a joint venture between Brazil's Rima Group and domestic investor group Clean Tech LLC, started silicon metal production at its new 36,000-metric-ton-per-year (t/yr) plant in Burnsville, MS. The Burnsville facility was the first silicon metal production facility to be built in the United States during the past 40 years (Mississippi Silicon, LLC, undated). GMI had been the sole merchant silicon metal producer in the United States.

Total Silicon Materials.—Data for all silicon materials that were produced in the United States in 2015—ferrosilicon, miscellaneous silicon alloys, and silicon metal—were derived from company responses to monthly and annual voluntary surveys 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.

Domestic production of total silicon materials has increased since 2005 with production in 2015 (411,000 t) approaching the most recent high of 430,000 t produced in 1997. 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 (fig. 1).

Semiconductor- and Solar-Battery-Grade Silicon.—In December, Wacker Chemie AG began startup operations at its new polycrystalline production facility in Charleston, TN. The plant, which had been under construction since 2011, has a production capacity of more than 20,000 t/yr of polycrystalline silicon and cost approximately \$2.5 billion to build (Wacker Chemie AG, undated, p. 3a, 12–13).

Consumption

Most ferrosilicon (including miscellaneous silicon alloys) was used to produce steel (77%) (table 4). More than 75% of the 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 2015 USGS Minerals Yearbook, volume I, Metals and Minerals, and in quarterly Mineral Industry Surveys.

In 2015, U.S. apparent consumption of silicon materials (ferrosilicon, miscellaneous silicon alloys, and silicon metal) was 661,000 t of contained silicon (table 1). Global apparent consumption of ferrosilicon was estimated by CRU International Ltd. to have decreased by approximately 17% to 4.61 Mt (contained silicon) in 2015 from 5.54 Mt in 2014; apparent consumption of silicon metal was estimated to have increased by about 3% to 2.49 Mt in 2015 from 2.42 Mt in 2014. The country with the largest year-over-year decrease in ferrosilicon apparent consumption in terms of tonnage was China (28%). Even with this decrease, China accounted for 53% of the world's ferrosilicon apparent consumption in 2015. Conversely, China experienced the largest year-over-year increase in silicon metal apparent consumption in terms of tonnage at 12% and accounted for 33% of global silicon metal consumption (CRU Bulk Ferroalloys Monitor, 2016a, b).

Prices

Ferrosilicon and silicon metal prices are affected by changes in supply to, and consumption requirements by, the aluminum, chemical, ferrous foundry, and steel industries. The average annual spot prices reported by Platts Metals Week in 2015 were 88.11 cents per pound for 75% ferrosilicon, and 126.63 cents per pound for silicon metal; prices for both of these categories were 10% less than their average prices in 2014 (table 1). The average annual North American transaction price for 50% ferrosilicon, as calculated from CRU Ryan's Notes weekly listings, was 101.19 cents per pound, a 6% decrease from that in 2014.

Average monthly spot prices for ferrosilicon and silicon metal decreased steadily throughout 2015. Ferrosilicon, 50% grade, was 106.50 cents per pound from January through May, was 98.00 cents per pound in July through November, and closed the year at 90.00 cents per pound, the lowest monthly average spot price in 6 years. The monthly average price for 75%-grade ferrosilicon began the year at 96.38 cents per pound, decreased to 90.50 cents per pound in June, and was 69.60 cents per pound at yearend. Monthly average spot prices for silicon metal decreased every month in 2015, from 142.38 cents per pound in January to 105.70 cents per pound in December.

Foreign Trade

Trade quantities discussed are based on contained weight. U.S. ferrosilicon exports increased slightly to 8,780 t, and their value increased by 12% to \$31.3 million, from those in 2014. Although the monthly average spot prices for ferrosilicon and silicon materials decreased in 2015 compared with those in 2014, the average unit value (dollars per metric ton) of exported ferrosilicon with greater than 55% silicon content (ferrosilicon trade category of "More than 55% silicon") increased by 14% in 2015. The two leading destinations, Canada (1,830 t) and Mexico (3,520 t), accounted for 61% of the total United States ferrosilicon exports in 2015 (table 5). Exports of silicon metal decreased by 19% to 36,800 t, and their value decreased by 23% to \$1.28 billion from those in 2014. Shipments of ultra-high-purity silicon containing more than 99.99% silicon accounted for 94% of total silicon metal exported and 97% of the total value of combined ferrosilicon and silicon metal exports.

U.S. ferrosilicon imports decreased by 13% to 162,000 t, and the value of those imports decreased by 19% to \$322 million compared with those in 2014. The largest decrease by tonnage in ferrosilicon imports was in the "55%–80% silicon, other" trade category with about 20,600 t, which was 13% less than that of 2014. Imports of "55%–80% silicon, more than 3% Ca" and "Magnesium ferrosilicon" also decreased in 2015; the remaining import trade categories increased in 2015 compared with 2014. Imports of "55%–80% silicon, other" accounted for 88% of total ferrosilicon imports and 81% of total ferrosilicon value (table 6). Russia (38%) was the leading source of total ferrosilicon imports, followed by China (25%), Canada (12%), and Venezuela (9%).

Silicon metal imports (139,000 t) increased slightly from those in 2014 and increased slightly in value to \$464 million from \$453 million in 2014. Silicon metal in the "99.00%–99.99% silicon" trade category accounted for 69% of the total quantity and 59% of the value, respectively, of all silicon metal imported in 2015. South Africa (26%) was the leading source of total silicon metal imports, followed by Brazil (20%), Canada (15%), and Australia (14%).

World Industry Structure

In 2015 and on a gross-weight basis, the leading producers of ferrosilicon and silicon metal, combined, were China (6.68 Mt), Russia (1.12 Mt), Norway (500,000 t), and the United States (325,000 t, net production). Excluding the United States, world production of ferrosilicon, on a gross-weight basis, was estimated to have been 7.27 Mt in 2015 compared with 8 Mt (revised) in 2014. The major ferrosilicon producers in 2015 were, in decreasing order, China (65%), Russia (15%), and Norway (5%); combined they accounted for 84% of total world ferrosilicon production (table 7).

World production of silicon metal, excluding that from the United States, was estimated to have been 2.54 Mt in 2015 compared with 2.3 Mt (revised) in 2014 (table 7). China was, by far, the leading producer of silicon metal in the world in 2015 with an estimated 1.95 Mt; this was 77% of the world's total silicon metal production. Other major producers of silicon metal in 2015 were, in decreasing order, Norway (6%), France (4%), and Brazil (3%); these four countries accounted for 89% of total world silicon metal production.

World Review

Brazil.—Brazil, which generates more than 70% of its energy from hydroelectric dams, continued to experience its worst drought in decades, which led to significant increases in electricity costs (Johnson and Berndt, 2016). The resulting high cost of electricity caused many ferrosilicon and silicon metal producers to slow or stop production as the Government imposed energy restrictions. By the first week of February, only 4 of the 17 members of the Brazilian ferroalloy trade association, Associação Brasileira dos Produtores de Ferroligas e de Silício Metálico, were in operation. Of those, only Companhia de Ferro Ligas da Bahia (Ferbasa) and Dow Corning Corp. produced ferrosilicon or silicon metal, respectively, during 2015 (Assalve, 2015b).

Early in the year, the high energy costs and uncertainty regarding its contract renewal with energy supplier Companhia Hidro-Elétrica do São Francisco (Chesf) led Ferbasa to reduce its ferrosilicon sales to meet existing obligations (Assalve, 2015a). However, in June Chesf and a group of energy-intensive consumers (including silicon material producers) concluded a new energy contract. Although the new base contract price increased by 22.5% compared with the price in the expiring energy contract, it was significantly less than the price that the companies would have had to pay on the open market had the old contract expired in June. This would have been more than three times the previous contract price or \$118 per megawatt hour (Assalve, 2015a). Ferbasa's production of 75%-grade ferrosilicon was approximately 56,000 t during the first 9 months of 2015, almost 8% less than that during the same period in 2014 (Evans, 2015). In November, Ferbasa's sales of ferrosilicon were approximately 4,000 t, a 33% decrease compared with that in November 2014 (Business News Americas, S.A., 2015).

China.—In 2015, China led the world in ferrosilicon and silicon metal production with a combined total of 6.68 Mt, the lowest combined production for China since 2011. Although silicon metal production increased in 2015 compared with 2014, combined production decreased by 7% owing to the 14% decrease in ferrosilicon production (table 7). The decrease in ferrosilicon production was likely related to the reduction in production capacity initiated by the Government of China. In 2015, China's Ministry of Industry and Information Technology announced plans to cut ferroalloys production capacity. About 85,000 t/yr of silicon metal and 16,100 t/yr of ferrosilicon production capacity was planned for elimination in the Guangxi Zhuang and Nei Mongol Autonomous Regions and Guizhou and Sichuan Provinces. In the Ningxia Hui Autonomous Region, 30,000 t/yr of ferrosilicon production capacity was to be eliminated (Guo, 2015a, b). It has been estimated that there were approximately 200 individual producers of silicon metal and 1,000 producers of ferrosilicon in China with a total production capacity of approximately 4 million metric tons per year (Mt/yr) and 11 Mt/yr, respectively (Roskill Information Services Ltd., 2014, p. 72, 75, 79, 80).

China's ferrosilicon and silicon metal exports both decreased in 2015. Ferrosilicon exports decreased by 40% to 246,000 t from 410,000 t exported in 2014. Ferrosilicon containing more than 55% silicon accounted for the bulk of the ferrosilicon exports at 209,000 t (85%). The leading countries of destination for this ferrosilicon grade were Japan (38%), the Republic of Korea (18%), and the United States (15%). China's silicon metal exports also decreased in 2015 by 11% to 776,000 t from 871,000 t in 2014. The leading countries of destination for China's silicon metal were Japan (22%) and the Republic of Korea (19%) (TEX Report, The, 2016a–c).

Some of the decrease in ferrosilicon exports was attributed to chemical explosions at China's Port of Tianjin in August. The explosions, described as some of the worst industrial disasters in Chinese history, were caused by the improper storage of chemicals; 165 people were killed and the port sustained \$1.1 billion in damage (Hernández, 2016). Following the explosions, shipments of ferrosilicon and calcium silicon

were delayed as they were classified as dangerous goods by the Government of China. Silicon metal exports were unaffected by the explosions as they were shipped primarily from the Port of Huangpu (Zhao and others, 2015).

Macedonia.—Sole ferrosilicon producer Jugohrom Ferroalloys Ltd., which has a 75%-grade ferrosilicon production capacity of about 72,000 to 84,000 t/yr, operated at 50% capacity from November 2014 through December 2015 because of Government requirements for air pollution control. Jugohrom reduced its greenhouse gas emissions by two-thirds and was given 2 years to meet new environmental standards. At yearend 2015, Jugohrom extended its reduction in ferrosilicon production to 30% of production capacity because of low market prices in Europe (Conway, 2016).

Malaysia.—OM Materials Sarawak SDN BHD became the first ferrosilicon producer in Malaysia in September 2014. In 2015, its first full year of production, OM Materials produced approximately 104,000 t of ferrosilicon (OM Holdings, Ltd., 2015, 2016).

Russia.—Russia exported 466,000 t of ferrosilicon in 2015, slightly more than the 456,000 t exported in 2014. Russia imported 18,400 t of ferrosilicon, more than double the 8,400 t imported in 2014. Imported ferrosilicon, greater than 55%-grade silicon, from Ukraine represented 44% of the total amount of ferrosilicon imported in 2015 (UN Comtrade, 2016).

Spain.—In December, Spain's Grupo FerroAtlántica, S.A. and U.S. silicon producer GSM completed their merger and finalized the creation of the new company Ferroglobe PLC. At the time of the merger, Ferroglobe was valued at \$3.1 billion, and ownership was to be split 57% by FerroAtlántica's parent company Grupo Villar Mir and 43% by GSM. The new company would account for about 12% to 13% of the world's total silicon metal market and would be the world's leading producer of silicon metal (Conway, 2015; Ferroglobe PLC, 2017).

Ukraine.—Privat Group's Stakhanov ferroalloys plant, once the leading producer of ferrosilicon in Ukraine with an average production capacity of 12,300 metric tons per month, was forced to close in August 2014 because of the fighting in the Lugansk region. The closure of the Stakhanov plant cut the country's total production of ferrosilicon by about 50%. To compensate for the closure of Stakhanov, Privat increased ferrosilicon production at its Zaporozhye ferroalloys plant and produced more than 90,000 t of ferrosilicon in 2015 (Sparks, 2015, 2016).

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 2015 USGS Minerals Yearbook, volume I, Metals and Minerals.

According to the World Steel Association (2016a), global crude steel production decreased by 3% in 2015 to 1.62 billion metric tons (Gt) compared with 1.67 Gt in 2014. China, the world's leading producer of raw steel, had a slight decrease in production to 803.8 Mt in 2015 from 822.7 Mt in 2014. U.S. crude steel production decreased by 11% to 79 Mt compared

with 88 Mt produced in 2014. World apparent consumption of finished steel products decreased by 2.9% to 1.5 Gt in 2015. China, the leading world consumer of steel products, decreased consumption by 5.4% to 672 Mt in 2015 from 711 Mt in 2014. The combined steel consumption in Brazil, China, India, and Russia decreased to 813 Mt from 855 Mt; these four countries accounted for about 54% of the world total in 2015. The World Steel Association's short-range forecast for global steel consumption was 1.501 Gt in 2016 and 1.510 Gt in 2017 (World Steel Association, 2016b).

Silicon metal is consumed primarily by the aluminum and chemical industries. Ferroglobe estimated world silicon metal consumption to be divided among the silicone (50%), aluminum (40%), and solar (10%) markets (Ferroglobe PLC, 2016, p. 27–29). Consumption of silicones in the United States was forecast to increase by 4.5% annually to \$4.4 billion in 2020. The fastest growing markets for silicones in the United States were expected to be the construction and medical industries; the industrial market would remain the dominant consumer (Freedonia Group, Inc., The, 2016). Consumption of silicon metal by the U.S. aluminum castings industry was expected to mirror the short- and long-term annual growth rate of 2.7% from 2015 to 2024 in domestic aluminum casting sales (Modern Casting, 2016, p. 33).

Consumption of polycrystalline silicon is predominately for solar-grade (90%) and semiconductor (10%) end uses (GTM Research, 2014). Continued growth in global solar demand was expected for the next few years and global polycrystalline production capacity was estimated to increase by 5% from 289,000 t/yr in 2015 to 304,800 t/yr in 2016 (PR Newswire, 2016; REC Silicon ASA, 2016; Roskill's Letter from Japan, 2016).

References Cited

- Assalve, Danielle, 2015a, Brazil extends low-priced energy to ferroalloy producers: American Metal Market, June 24. (Accessed January 27, 2017, via <http://www.amm.com/>.)
- Assalve, Danielle, 2015b, Energy prices stifle ferroalloys in Brazil: American Metal Market, February 14. (Accessed January 27, 2017, via <http://www.amm.com/>.)
- Business News Americas, S.A., 2015, Ferbasa's net sales growth spikes on stronger dollar; Business News Americas, S.A., December 18. (Accessed January 26, 2017, via <http://www.bnamericas.com>.)
- Conway, Declan, 2015, Globe, FerroAtlantica complete merger: Metal-Pages, December 24. (Accessed January 30, 2017, via <http://www.metal-pages.com/>.)
- Conway, Declan, 2016, Jugohrom Ferroalloys restarts ferro-silicon output: Argus Media group Metal-Pages, March 18. (Accessed January 30, 2017, via <http://www.metal-pages.com/>.)
- CRU Bulk Ferroalloys Monitor, 2016a, Ferrosilicon—Ferrosilicon supply/demand balance: CRU Bulk Ferroalloys Monitor, May.
- CRU Bulk Ferroalloys Monitor, 2015b, Silicon metal—Silicon metal supply/demand balance: CRU Bulk Ferroalloys Monitor, May.
- Evans, John, 2015, Ferbasa Q3 ferro-chrome production down 38.1 pc: Metal-Pages, November 9. (Accessed June 6, 2016, via <http://www.metal-pages.com/>.)
- Ferroglobe PLC, 2015, Globe Specialty Metals and GrupoFerroAtlántica clear regulatory process and complete business combination: Madrid, Spain, and Miami, FL, Ferroglobe PLC news release, December 23. (Accessed February 21, 2017, at <http://www.ferroatlantica.es/press/news/globe-specialty-metals-and-grupo-ferroatl%C3%A9ntica-clear-regulatory-process-and-complete-business-combination/?lang=en>.)
- Ferroglobe PLC, 2016, Ferroglobe—Investor presentation: London, United Kingdom, Ferroglobe PLC, May 9, 35 p. (Accessed January 30, 2017, at http://investor.ferroglobe.com/common/download/download.cfm?companyId=AMDA-S5TP82&fileid=925388&filekey=06493FD0-3C33-49AE-A17E-63A4ED53FEB3&filename=Ferroglobe_-_Investor_Presentation.pdf.)
- Ferroglobe PLC, 2017, Ferroglobe—Investor presentation: London, United Kingdom, Ferroglobe PLC, January 26, 13 p. (Accessed February 23, 2017, at http://files.shareholder.com/downloads/AMDA-S5TP82/2550256923x0x890793/CFE050BE-EFCF-45C5-B36E-E2175021C697/Ferroglobe_-_Investor_Presentation.pdf.)
- Freedonia Group, Inc., The, 2016, Silicones—Demand and sales forecasts, market share, market size, market leaders: Cleveland, OH, The Freedonia Group study #3391 brochure, March, 278 p. (Accessed January 31, 2017, at <http://www.freedoniagroup.com/Silicones.html>.)
- Johnson, Slade, and Berndt, Kirstin, 2016, Hydroelectric plants account for more than 70% of Brazil's electric generation: U.S. Energy Information Administration, August 11. (Accessed January 27, 2017, at <http://www.eia.gov/todayinenergy/detail.php?id=27472>.)
- Guo, Gretel, 2015a, China to shutter 904,000 t/yr ferro-alloys capacity in 2015: Metal-Pages, June 8. (Accessed June 1, 2016, via <http://www.metal-pages.com/>.)
- Guo, Gretel, 2015b, China's Ningxia to shutter 74,000 t/yr ferro-alloys capacity in 2015: Metal-Pages, June 17. (Accessed June 1, 2016, via <http://www.metal-pages.com/>.)
- GTM Research, 2014, Polysilicon 2015–2018—Supply, demand, cost and pricing: Boston, MA, GTM Research, October. (Accessed January 31, 2017, at <https://www.greentechmedia.com/research/report/polysilicon-2015-2018>.)
- Hernández, Javier, 2016, China finds Tianjin explosions were result of mismanagement: New York Times, February 5. (Accessed January 27, 2017, at https://www.nytimes.com/2016/02/06/world/asia/tianjin-explosions-were-result-of-mismanagement-china-finds.html?_r=0.)
- Mississippi Silicon, LLC, [undated], Mississippi Silicon—Key facts: Burnsville, MS, Mississippi Silicon, LLC. (Accessed January 25, 2017, at <http://www.missisilicon.com/wp-content/uploads/2015/11/MS-Silicon-Key-Facts.pdf>.)
- Modern Casting, 2016, 2016 forecast—Small gains in short-term: Lansing, MI, Modern Casting, January, p. 30–34. (Accessed January 30, 2017, at <http://content.yudu.com/web/y5b2/0A1snzj/ModernCastingJan2016/flash/resources/index.htm>.)
- OM Holdings, Ltd., 2015, Preliminary final report—Highlights: Singapore, Malaysia, OM Holdings, Ltd., August 28. (Accessed June 15, 2016, at http://www.omholdingsltd.com/news_announce15/12.pdf.)
- OM Holdings, Ltd., 2016, December 2015 quarterly production and market update: Singapore, Malaysia, OM Holdings, Ltd., January 29. (Accessed June 10, 2016, at http://www.omholdingsltd.com/news_announce16/02.pdf.)
- PR Newswire, 2016, Polysilicon market by end-use industry and electronics, and region—Global forecast to 2021: New York, NY, PR Newswire, October 25. (Accessed January 31, 2017, at <http://www.prnewswire.com/news-releases/polysilicon-market-by-end-use-industry-and-electronics-and-region---global-forecast-to-2021-300351307.html>.)
- REC Silicon ASA, 2016, REC Silicon—Fourth quarter 2015 presentation: Moses Lake, WA, REC Silicon ASA, February 12, 39 p. (Accessed January 31, 2017, at <http://www.recsilicon.com/downloads/corporate-downloads?category=all&year=2016>.)
- Roskill Information Services Ltd., 2014, Silicon and ferrosilicon—Global industry markets and outlook (14th ed.): London, United Kingdom, Roskill Information Services Ltd., 297 p.
- Roskill's Letter from Japan, 2016, Polycrystalline silicon—5% rise in world capacity forecast in 2016: Roskill's Letter from Japan, no. 479, July, p. 1.
- Sparks, Polina, 2015, Ukraine ferro-alloy output drops 22.7 pc on cutbacks, Stakhanov [CORRECTED]: Metal-Pages, September 24. (Accessed January 27, 2017, via <http://www.metal-pages.com/>.)
- Sparks, Polina, 2016, Ukraine ferro-alloy plants see demand pick up: Argus Media group Metal-Pages, April 22. (Accessed January 30, 2017, via <http://www.metal-pages.com/>.)
- TEX Report, The, 2016a, China's export of ferro-silicon in 2015 is 209,204 tons: The TEX Report, v. 48, no. 11352, February 9, p. 11.
- TEX Report, The, 2016b, China's export of silicon metal in 2015 is 775,541 tons: The TEX Report, v. 48, no. 11353, February 10, p. 9–10.
- TEX Report, The, 2016c, China's import and export results of ferroalloys in December 2015: The TEX Report, v. 48, no. 11349, February 4, p. 9.
- UN Comtrade, 2016, UN comtrade database: Geneva, Switzerland, United Nations. (Accessed January 30, 2014, via <http://comtrade.un.org/>.)
- Wacker Chemie AG, [undated], Annual report 2015: Adrian, MI, Wacker Chemie AG, 286 p. (Accessed January 25, 2017, at https://www.wacker.com/cms/media/cn/documents/wacker_group/annual_report_15.pdf.)

World Steel Association, 2016a, Steel statistical yearbook 2016: London, United Kingdom, World Steel Association, 128 p. (Accessed January 30, 2017, at <http://www.worldsteel.org/steel-by-topic/statistics/Steel-Statistical-Yearbook-.html>.)

World Steel Association, 2016b, Worldsteel short range outlook 2016–2017: London, United Kingdom, World Steel Association press release, October 11. (Accessed January 30, 2017, at <https://www.worldsteel.org/media-centre/Press-releases/2016/worldsteel-Short-Range-Outlook-2016---2017.html>.)

Zhao, Ohmin, Mu, Alice, Hao, Heming, and Chao, Mikaela, 2015, Safety checks at China's Tianjin delay exports: Metal-Pages, September 17. (Accessed January 26, 2017, via <http://www.metal-pages.com/>.)

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 Ryan's Notes.
Platts Metals Week.
Silicon. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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.

TABLE 1
SALIENT SILICON STATISTICS¹

(Contained silicon, unless otherwise noted)

	2011	2012	2013	2014	2015
United States:					
Production:					
Ferrosilicon	W	W	W	W	W
Silicon metal ²	W	W	W	W	W
Total silicon materials ³	349 ^r	390 ^r	392 ^r	401 ^r	411
Exports:					
Ferrosilicon	20	12	10	9	9
Silicon metal	79	75	38	45	37
Imports for consumption:					
Ferrosilicon	156	173	159	186	162
Silicon metal	187	136	118	139	139
Apparent consumption:					
Ferrosilicon	W	W	W	W	W
Silicon metal ²	W	W	W	W	W
Total silicon materials ³	587 ^r	607 ^r	631 ^r	670 ^r	661
Price, average:					
Ferrosilicon, 50% Si ⁴	111.36 ^r	100.44 ^r	102.56 ^r	107.81 ^r	101.19
Ferrosilicon, 75% Si ⁵	102.19 ^r	91.66	94.27	98.35	88.11
Silicon metal ⁵	157.61 ^r	127.34	122.39	140.39	126.63
World production, gross weight:					
Ferrosilicon ⁶	7,870 ^r	8,220	8,610 ^r	8,010 ^r	7,270 ^e
Silicon metal ⁷	2,030	1,770	2,060 ^r	2,310 ^r	2,540 ^e
Total silicon materials ^{3,8}	10,300	10,400	11,000 ^r	10,700 ^r	10,100 ^e

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

¹Data 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 Ryan's Notes North American transaction prices based on weekly averages.

⁵Platts Metals Week 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
2014:			
Ferrosilicon	W	W	W
Silicon metal	W	W	W
Total silicon materials [†]	526,000	358,000	37,900
2015:			
Ferrosilicon	W	W	W
Silicon metal	W	W	W
Total silicon materials	514,000	318,000	45,100

[†]Revised. W Withheld to avoid disclosing company proprietary data.

¹Data 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 2015¹

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

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

²Owned by Ferroglobe PLC following the merger of Globe Specialty Metals, Inc. with Grupo FerroAtlántica, S.A. in December 2015.

³Owned by Rima Industrial S.A. and CleanTech, LLC.

⁴A joint venture between Globe Metallurgical, Inc. and Dow Corning Corp.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND STOCKS OF SILICON FERROALLOYS AND METAL IN THE
UNITED STATES IN 2015^{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	(9)	(10)	34,500	(10)	(10)	(10)
Stainless and heat-resisting	--	(10)	44,700	286	(10)	(10)
Full alloy	--	(10)	8,880	(10)	(10)	--
Electric steel	--	--	(10)	--	--	(10)
Electric and tool	--	--	(10)	--	--	--
Unspecified	--	47,900	32,700	1,310	2,890	5,620
Total	--	47,900	121,000	1,600	2,890	5,620
Cast irons	14,400	18,600	21,100	(11)	9,720	17,400
Superalloys	--	--	(12)	37	--	--
Welding	--	(12)	--	(11)	--	--
Wear and corrosion	--	(12)	(12)	(11)	(9)	--
Aluminum	--	--	(12)	(11)	--	(9)
Copper	--	--	--	(11)	--	--
Nickel	--	--	(12)	(11)	(9)	--
Tungsten	--	--	--	(11)	--	--
Other alloy	--	--	--	--	(9)	--
Chemical carbides	--	--	--	--	(9)	--
Alloys, excluding superalloys and alloy steel	--	--	--	27,800 ¹³	--	--
Miscellaneous and unspecified	--	1,320	275	W ¹⁴	(9)	--
Grand total	14,400	67,800	142,000	W	12,600	23,000
Consumers' stocks, December 31	170	897	8,640	12,700	541	922

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

¹Data 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% to 24% silicon content.

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

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

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

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

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

⁹Included with "Cast irons" to avoid disclosing company proprietary data.

¹⁰Included with "Steel: Unspecified" to avoid disclosing company proprietary data.

¹¹Included with "Alloys, excluding superalloys and alloy steel" to avoid disclosing company proprietary data.

¹²Included with "Miscellaneous and unspecified" 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 2015^{1,2}

(Metric tons, unless otherwise specified)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
More than 55% silicon:			
Austria	6	3	\$8,690
Brazil	81	50	165,000
Canada	1,690	1,010	2,630,000
Colombia	65	48	172,000
Costa Rica	2	1	2,910
India	50	30	35,500
Japan	723	542	1,400,000
Malaysia	6	4	10,000
Mexico	3,130	1,890	7,390,000
Switzerland	3	2	4,250
Other (1 country)	1	1	7,140
Total	5,760	3,580	11,800,000
Other ferrosilicon:			
Brazil	243	122	564,000
Canada	1,630	813	1,930,000
Japan	299	137	521,000
Korea, Republic of	760	336	886,000
Mexico	3,350	1,630	8,180,000
Netherlands	420	184	215,000
Poland	311	95	589,000
Switzerland	140	63	255,000
Turkey	1,440	655	2,500,000
United Kingdom	1,920	939	2,880,000
Other (8 countries)	466	218	905,000
Total	11,000	5,190	19,400,000
Total ferrosilicon	16,700	8,780	31,300,000
Metal:			
More than 99.99% silicon:			
China	10,300	10,300	250,000,000
Germany	612	612	19,400,000
Hong Kong	1,020	1,020	26,000,000
Italy	318	318	12,700,000
Japan	10,700	10,700	557,000,000
Korea, Republic of	4,030	4,030	151,000,000
Malaysia	491	491	41,100,000
Norway	689	689	20,800,000
Singapore	977	977	22,800,000
Taiwan	5,010	5,010	150,000,000
Other (41 countries)	518	518	26,100,000
Total	34,600	34,600	1,280,000,000
99.00%–99.99% silicon:			
Austria	41	41	57,700
China	3	3	3,780
Costa Rica	17	17	24,200
India	30	29	43,800
Mexico	22	22	60,900
Netherlands	7	7	9,500
Saudi Arabia	63	63	318,000
Taiwan	11	11	22,000
Thailand	13	13	18,200
United Kingdom	7	7	10,200
Other (4 countries)	6	6	20,400
Total	220	219	589,000

See footnotes at end of table.

TABLE 5—Continued
 U.S. EXPORTS OF FERROSILICON AND SILICON METAL IN 2015^{1,2}

(Metric tons, unless otherwise specified)

Country	Gross weight	Contained weight	Value
Metal—Continued:			
Other silicon:			
Belgium	593	576	865,000
Canada	699	679	2,080,000
China	94	92	125,000
Hong Kong	26	25	\$98,700
Korea, Republic of	47	46	294,000
Mexico	134	130	200,000
South Africa	62	60	168,000
Taiwan	80	77	863,000
Thailand	40	39	79,200
United Kingdom	135	132	357,000
Other (11 countries)	35	33	173,000
Total	1,950	1,890	5,300,000
Total silicon metal	36,800	36,800	1,280,000,000

¹Countries listed are the leading importers in terms of quantity (gross weight).

²Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL
IN 2015^{1,2}

(Metric tons, unless otherwise specified)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
55%–80% silicon, more than 3% Ca:			
Argentina	19	12	\$34,100
Canada	63	47	155,000
China	4,020	3,020	4,600,000
France	588	360	1,650,000
Germany	12	9	35,900
Russia	10	5	14,300
Saudi Arabia	18	11	40,200
South Africa	364	241	794,000
Spain	1	(3)	3,070
Taiwan	115	85	198,000
Total	5,210	3,790	7,530,000
55%–80% silicon, other:			
Canada	13,900	10,200	29,600,000
China	46,500	34,900	55,900,000
France	1,870	1,290	5,280,000
Iceland	8,100	6,130	10,200,000
Malaysia	2,470	1,830	2,940,000
Russia	79,900	61,000	107,000,000
South Africa	9,560	7,180	15,200,000
Spain	2,080	1,580	3,180,000
Venezuela	18,100	14,100	21,500,000
Vietnam	1,650	1,240	1,590,000
Other (8 countries)	3,730	2,780	8,110,000
Total	188,000	142,000	260,000,000
80%–90% ferrosilicon:			
Germany	280	231	237,000
Sweden	4	3	3,360
Total	283	234	241,000
More than 90% ferrosilicon:			
Australia	15	14	4,500
South Africa	544	500	846,000
Total	559	513	851,000
Magnesium ferrosilicon:			
Argentina	1,190	527	1,490,000
Brazil	63	28	110,000
Canada	12,000	5,440	23,800,000
China	405	187	663,000
France	141	64	246,000
Germany	155	71	211,000
India	1,660	767	2,720,000
Norway	1,030	485	1,980,000
Total	16,700	7,570	31,200,000
Other ferrosilicon:			
Brazil	95	42	76,500
Canada	11,500	4,190	13,300,000
China	14,800	2,830	7,340,000
France	108	58	312,000
Germany	24	10	75,900
India	155	58	182,000
Russia	87	43	131,000
Slovakia	181	65	218,000

See footnotes at end of table.

TABLE 6—Continued
 U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL
 IN 2015^{1,2}

(Metric tons, unless otherwise specified)

Country	Gross weight	Contained weight	Value
Ferrosilicon:—Continued			
Other ferrosilicon:—Continued			
South Africa	9	4	21,100
United Kingdom	18	3	23,900
Total	27,000	7,290	21,700,000
Total ferrosilicon	237,000	162,000	322,000,000
Metal:			
More than 99.99% silicon:			
Brazil	8,720	8,720	\$29,100,000
China	109	109	2,050,000
Germany	1,890	1,890	58,200,000
Japan	79	79	6,130,000
Kazakhstan	108	108	255,000
Korea	124	124	2,150,000
Mexico	15	15	240,000
Norway	310	310	1,280,000
Poland	33	33	357,000
Taiwan	97	97	2,230,000
Other (19 countries)	41	41	3,400,000
Total	11,500	11,500	105,000,000
99.00%–99.99% silicon:			
Australia	17,300	17,000	48,900,000
Brazil	16,800	16,700	45,800,000
Canada	4,580	4,550	12,800,000
France	1,090	1,080	3,270,000
Kazakhstan	1,810	1,800	4,340,000
Laos	3,260	3,230	8,910,000
Norway	8,290	8,230	24,500,000
South Africa	36,500	36,200	105,000,000
Spain	1,840	1,820	5,520,000
Thailand	4,940	4,900	12,400,000
Other (5 countries)	481	370	1,100,000
Total	96,900	95,900	273,000,000
Other silicon:			
Australia	2,580	2,530	7,020,000
Bhutan	1,260	1,240	2,680,000
Brazil	2,970	2,930	8,030,000
Canada	17,000	16,700	47,300,000
China	248	239	334,000
Germany	227	213	297,000
India	360	355	871,000
Kazakhstan	896	873	2,240,000
Norway	6,200	6,030	14,400,000
United Kingdom	342	335	886,000
Other (8 countries)	581	558	1,390,000
Total	32,600	32,000	85,400,000
Total silicon metal	141,000	139,000	464,000,000

¹Countries listed are the leading exporters in terms of quantity.

²Data are rounded to no more than three significant digits; may not add to totals shown.

³Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 7
FERROSILICON AND SILICON METAL: WORLD PRODUCTION, BY COUNTRY^{1,2,3}

(Metric tons, gross weight)

Country and commodity ⁴	2011	2012	2013	2014	2015 ^e
Argentina, ferrosilicon ^c	18,000	14,000	15,000	17,000	12,700
Australia, silicon metal ^c	30,000	30,000	30,000	48,000	48,000
Bhutan, ferrosilicon ^{c,5}	96,711 ⁶	107,819 ⁶	110,000	110,000	120,000
Bosnia and Herzegovina:					
Ferrosilicon	(7)	(7)	(7)	(7)	(7)
Silicon metal ⁸	15,468 ^r	13,804 ^r	13,627 ^r	15,395 ^r	16,109 ⁶
Total	15,468 ^r	13,804 ^r	13,627 ^r	15,395 ^r	16,109 ⁶
Brazil: ^c					
Ferrosilicon	145,000	145,000	147,000	98,000	74,600
Silicon metal	132,000	133,000	137,000	92,300	70,000
Total	277,000	278,000	284,000	190,000	145,000
Canada: ^c					
Ferrosilicon	31,039 ⁶	31,979 ⁶	38,871 ⁶	32,000 ^r	38,000
Silicon metal	30,000	30,000	12,000	30,000	30,000
Total	61,000	62,000	50,900	62,000 ^r	68,000
China: ^c					
Ferrosilicon	5,400,000	5,760,000	6,000,000	5,500,000	4,730,000
Silicon metal	1,350,000	1,130,000	1,450,000 ^r	1,700,000 ^r	1,950,000
Total	6,750,000	6,890,000	7,450,000 ^r	7,200,000 ^r	6,680,000
Egypt, ferrosilicon ^{c,9}	55,500 ^r	55,300 ^r	50,800 ^r	61,500 ^r	61,700
France: ^c					
Ferrosilicon	71,500	63,300	49,600	40,000 ^r	35,000
Silicon metal	104,000	95,200	100,000	100,000	100,000
Total	176,000	159,000	150,000	140,000 ^r	135,000
Germany, silicon metal ^c	30,134 ^{6,10}	29,000	30,000 ^r	28,000	30,000
Iceland, ferrosilicon	120,076	131,818	125,204	110,000 ^{r,c}	115,000
India, ferrosilicon ¹¹	86,000 ^r	90,000 ^r	92,013 ^r	92,014 ^r	92,000
Kazakhstan:					
Ferrosilicon	1,683	494	472	334 ^r	NA
Silicon metal	8,000	8,000 ^r	-- ^r	1,834 ^r	6,000
Total	9,683	8,494 ^r	472 ^r	2,168 ^r	6,000
Laos, silicon metal ⁵	3,001	15,301	11,972	9,528	9,500
Macedonia, ferrosilicon	56,167	42,402	72,279	73,014	45,698 ⁶
Malaysia, ferrosilicon	--	--	--	8,641 ^r	104,000
Norway: ^c					
Ferrosilicon	230,000 ⁶	250,000	349,389 ^{r,6}	350,000 ^r	350,000
Silicon metal	175,000	150,000	150,000 ⁶	150,000	150,000
Total	405,000	400,000	499,389 ^{r,6}	500,000 ^r	500,000
Poland, ferrosilicon ^c	72,668 ⁶	78,115 ⁶	75,500	75,500	72,000
Russia:					
Ferrosilicon	1,026,170	1,036,930	1,012,740	1,026,190 ^r	1,059,000 ⁶
Silicon metal ^c	57,900 ⁶	52,500 ⁶	55,000 ^r	60,000 ^r	60,000
Total ^e	1,084,070 ⁶	1,089,430 ⁶	1,070,000 ^r	1,090,000 ^r	1,120,000
Slovakia, ferrosilicon	38,771	36,869	41,664	39,000 ^e	37,500
South Africa:					
Ferrosilicon	126,200	83,000	78,400	78,400 ^e	78,400
Silicon metal	58,800	53,000	34,000	34,000 ^e	34,000
Total	185,000	136,000	112,400	112,000 ^e	112,000
Spain: ^c					
Ferrosilicon	69,700	68,600	80,500	80,500	80,000
Silicon metal	34,800	27,200	29,200	29,200	30,000
Total	105,000	95,800	110,000	110,000	110,000
Turkey, ferrosilicon ^c	2,000	2,000	2,000	NA ^r	NA
Ukraine, ferrosilicon	150,900	150,265 ^r	191,207 ^r	142,300 ^r	90,200
United States:					
Ferrosilicon	W	W	W	W	W
Silicon metal	W	W	W	W	W
Total ¹²	380,000 ^r	368,000 ^r	337,000 ^r	361,000 ^r	325,000 ⁶
Uzbekistan, silicon metal ^c	--	1,700	6,000	7,000	10,000

See footnotes at end of table.

TABLE 7—Continued
 FERROSILICON AND SILICON METAL: WORLD PRODUCTION, BY COUNTRY^{1,2,3}

(Metric tons, gross weight)

Country and commodity ⁴	2011	2012	2013	2014	2015 ^e
Venezuela, ferrosilicon ^e	70,000 ⁶	72,300	74,300	74,300	74,300
Grand total ¹²	10,300,000	10,400,000	11,000,000 ^r	10,700,000 ^r	10,100,000
Of which:					
Ferrosilicon ¹³	7,870,000 ^r	8,220,000	8,610,000 ^r	8,010,000 ^r	7,270,000
Silicon metal ¹⁴	2,030,000	1,770,000	2,060,000 ^r	2,310,000 ^r	2,540,000
U.S. total silicon materials ¹²	380,000 ^r	368,000 ^r	337,000 ^r	361,000 ^r	325,000 ⁶

^eEstimated. ^rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total." NA Not available. -- Zero.

¹Grand totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Includes data available through August 22, 2016.

³Does not include semiconductor and solar grades of silicon metal.

⁴In addition to the countries listed, Iran and Uruguay are thought to have produced ferrosilicon and Thailand is thought to have produced silicon metal, but production information was inadequate to make reliable estimates of output.

⁵Exports.

⁶Reported figure.

⁷Country was a net importer of ferrosilicon.

⁸Net exports.

⁹Estimated or reported on a fiscal-year basis, which is from July 1 to June 30.

¹⁰Sales.

¹¹Estimated or reported on a fiscal-year basis, which is from April 1 to March 31.

¹²Includes total U.S. net production of ferrosilicon and silicon metal.

¹³Does not include total U.S. net production of ferrosilicon.

¹⁴Does not include total U.S. net production of silicon metal.

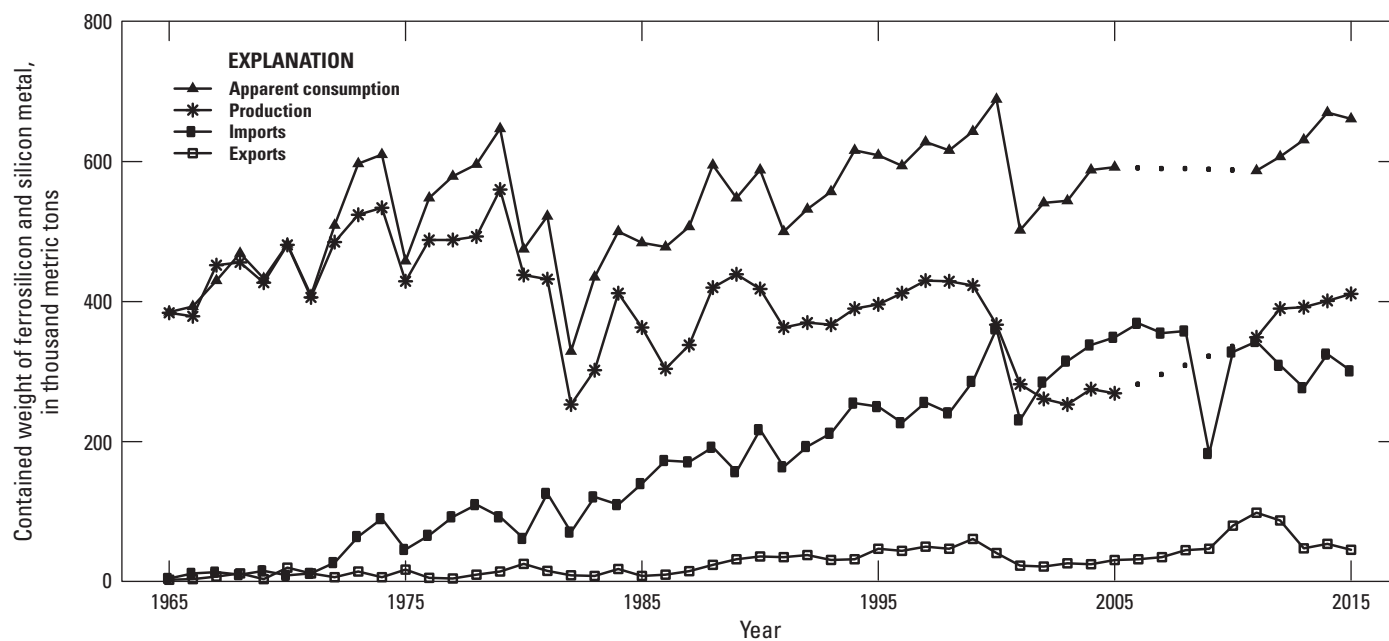


Figure 1. Gross domestic production, U.S. imports and exports, and domestic apparent consumption of ferrosilicon and silicon metal, on a contained-weight basis, from 1965 through 2015. Silicon metal refers to silicon metal containing less than 99.9% silicon. Data for silicon metal production and apparent 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. Census Bureau, U.S. Geological Survey (U.S. Bureau of Mines for data from 1965 to 1994).