



# 2016 Minerals Yearbook

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## SILICON [ADVANCE RELEASE]

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# SILICON

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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 2016, total gross domestic ferrosilicon and silicon metal production was 384,000 metric tons (t) of contained silicon (table 1). This was a 7% decrease compared with 2015 production. On the basis of contained silicon, U.S. exports of silicon products increased from 46,000 t in 2015 to 67,000 t in 2016, a 46% increase. U.S. imports decreased from 302,000 t in 2015 to 277,000 t in 2016, an 8% decrease. Total U.S. apparent consumption of silicon materials was 601,000 t in 2016, which was a 9% decrease from that in 2015 (fig. 1, table 1). U.S. annual averages of monthly average spot prices also decreased in 2016; silicon metal decreased by 28%, 75%-grade ferrosilicon decreased by 20%, and 50%-grade ferrosilicon decreased by 18% compared with the annual average prices in 2015. Combined world production of ferrosilicon and silicon metal decreased by 3% to 9.96 million metric tons (Mt) on a gross-weight basis compared with 10.2 Mt (revised) in 2015 (table 7). China was the leading producer of these silicon materials, providing 65% of the world total.

Silicon is a light chemical element with metallic and nonmetallic characteristics. Silicon is rarely found as an element in nature; it combines with oxygen and other elements to form silicates, which compose more than 90% of the Earth's crust. Silica (SiO<sub>2</sub>) 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 Ferrolobe PLC. Ferrolobe 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 Corp.; GMI; Mississippi Silicon, LLC; and WVA Manufacturing, LLC (table 3).

**Total Silicon Materials.**—Data for all silicon materials that were produced in the United States in 2016—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.

Annual domestic production of total silicon materials (contained silicon) decreased in 2016 (384,000 t) compared with 2015 production (411,000 t). This was the first decrease in year-on-year annual production since 2005. 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.**—In April, Wacker Chemie AG officially opened its new polycrystalline production facility in Charleston, TN. The plant has 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). 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 2016 USGS Minerals Yearbook, volume I, Metals and Minerals, and in the quarterly Mineral Industry Surveys.

In 2016, U.S. apparent consumption of silicon materials (ferrosilicon, miscellaneous silicon alloys, and silicon metal) was 601,000 t of contained silicon (table 1). Global apparent consumption of ferrosilicon was estimated by CRU International Ltd. to have increased by approximately 21% to 5.563 Mt (contained silicon) in 2016 from 4.606 Mt in 2015; however, this was only a slight increase from 2014 global apparent consumption of 5.556 Mt. Apparent consumption of silicon metal was estimated to have increased by about 6% to 2.642 Mt in 2016 from 2.497 Mt in 2015. The country with the largest

year-over-year increases in ferrosilicon and silicon metal apparent consumption in terms of tonnage was China, with increases of 35% and 12%, respectively. China accounted for 59% of global apparent ferrosilicon consumption and 35% of apparent silicon metal consumption (CRU Bulk Ferroalloys Monitor, 2017a, 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 2016 were 70.76 cents per pound for 75% ferrosilicon and 91.14 cents per pound for silicon metal; prices for both of these categories were 20% and 28% less, respectively, than their average prices in 2015 (table 1). The average annual North American transaction price for 50% ferrosilicon, as calculated from CRU Ryan's Notes weekly listings, was 82.70 cents per pound, an 18% decrease from that in 2015.

Average monthly spot prices for ferrosilicon were flat for the first 10 months of 2016 with prices increasing in November and December. Average monthly spot prices for silicon metal decreased in the first quarter of 2016 and remained relatively flat during the second and third quarters with prices increasing in November and December. Ferrosilicon, 50% grade, was 82.00 cents per pound from January through October and closed the year at 88.78 cents per pound, the lowest monthly average spot price since 2009. The monthly average price for 75%-grade ferrosilicon began the year at 68.63 cents per pound and was 81.88 per pound at yearend. The monthly average spot price for silicon metal was 101.5 cents per pound in January, decreased to 86.94 cents per pound in April, and was 98.75 cents per pound in December. The annual average of monthly average spot prices for 75%-grade ferrosilicon and silicon metal were the lowest they have been since 2009 and 2006, respectively.

## Foreign Trade

Trade quantities discussed are based on contained weight. U.S. ferrosilicon exports decreased 19% to 7,111 t, and their value decreased by 25% to \$23.4 million, from those in 2015. 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") decreased by 6% in 2016 and exported ferrosilicon with less than 55% silicon content (ferrosilicon trade category of "Other ferrosilicon") decreased by 8% compared with the 2015 unit value. The two leading destinations, Canada (1,630 t) and Mexico (3,280 t), accounted for 69% of the total United States ferrosilicon exported in 2016 (table 5). Exports of silicon metal increased by 61% to 59,600 t, and their value increased by 27% to \$1.62 billion from those in 2015. The two leading destinations of United States silicon metal, Japan (21,600 t) and Taiwan (16,600 t), accounted for 64% of United States silicon metal exports in 2016. 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 4% to 155,000 t, and the value of those imports decreased by 24% to \$246 million compared with those in 2015. The largest decrease by tonnage in ferrosilicon imports was in the "55%–80% silicon, other" trade category with about 9,000 t, which was 6% less than 2015. Imports of "80%–90% ferrosilicon" and "Other ferrosilicon" also decreased in 2016; the remaining import trade categories increased in 2016 compared with 2015. Imports of "55%–80% silicon, other" accounted for 86% of total ferrosilicon imports and 76% of total ferrosilicon value (table 6). Russia (26%) was the leading source of total ferrosilicon imports, followed by Brazil (17%) and Canada (13%).

Silicon metal imports (122,000 t) decreased by 13% in quantity from those in 2015 and decreased by 18% in value to \$379 million from \$463 million in 2015. Silicon metal in the "99.00%–99.99% silicon" trade category accounted for 75% of the total quantity and 57% of the value, respectively, of all silicon metal imported in 2016. Brazil (26%) was the leading source of total silicon metal imports, followed by South Africa (18%) and Canada (16%).

## World Industry Structure

In 2016 on a gross-weight basis, the leading producers of ferrosilicon and silicon metal, combined, were China (6.50 Mt), Russia (1.12 Mt), Norway (500,000 t), and the United States (310,000 t, net production). Excluding the United States, world production of ferrosilicon, on a gross-weight basis, was estimated to have been 6.87 Mt in 2016 compared with 7.35 Mt (revised) in 2015. The major ferrosilicon producers in 2016 were, in decreasing order, China (63%), Russia (15%), and Norway (5%); together they accounted for 83% of total world ferrosilicon production (table 7).

World production of silicon metal, excluding that by the United States, was estimated to have been 2.78 Mt in 2016 compared with 2.55 Mt (revised) in 2015 (table 7). China was, by far, the leading producer of silicon metal in the world in 2016 with an estimated 2.20 Mt; this was 79% of the world's total silicon metal production. Other major producers of silicon metal in 2016 were, in decreasing order, Norway (5%), France (4%), and Brazil (3%); these four countries accounted for 91% of total world silicon metal production.

## World Review

**Brazil.**—Brazil's crude steel production was 30.2 Mt in 2016, a 9.2% decrease compared with 2015 production (SteelOrbis, 2017). Steel production has 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). Ferroalloy producers in Minas Gerais and other regions of Brazil stopped or reduced production to about 20% of capacity owing to low demand as well as high costs and uncertainty with the nation's power supply (Evans, 2016).

**China.**—In 2015, China led the world in ferrosilicon and silicon metal production with a combined estimated total of

6.5 Mt, the lowest combined production for China since 2010 (Schnebele, 2016). Although silicon metal production increased in 2016 compared with that in 2015, combined production decreased by 3% owing to the 9% decrease in ferrosilicon production (table 7).

China's ferrosilicon and silicon metal exports both decreased in 2016. Ferrosilicon exports decreased by 7% to 228,000 t from 246,000 t exported in 2015. Ferrosilicon containing more than 55% silicon accounted for the bulk of the ferrosilicon exports at 192,000 t (84%). The leading countries of destination for this ferrosilicon grade were Japan (35%), the Republic of Korea (29%), and India (6%). China's silicon metal exports also decreased in 2016 by 9% to 650,000 t from 780,000 t in 2015. The leading countries of destination for Chinese silicon metal were Japan (23%) and the Republic of Korea (20%) (UN Comtrade, 2017).

China imported 143,000 t of silicon metal (greater than 99.99% silicon) in 2016, a 22% increase from the 117,600 t imported in 2015 (UN Comtrade, 2017). The portion of imported silicon metal (greater than 99.99% silicon) originating from the United States has steadily declined since 2014 owing to the tariffs imposed on the United States by the Government of China's Ministry of Commerce (Ministry of Commerce People's Republic of China, 2014). In 2014, 21% of the silicon metal (greater than 99.99% silicon) imported by China originated from the United States, but this decreased to 4% in 2016 (UN Comtrade, 2017).

**Macedonia.**—Sole ferrosilicon producer Jugohrom Ferroalloys Ltd. suspended production in November when it failed to install Government-required pollution reduction systems by the October 2016 deadline. The plant had operated at half capacity from November 2014 through December 2015 and temporarily idled two furnaces at the beginning of 2016 because of air pollution control requirements (Conway, 2016b). The particulate matter in the air around the plant was 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). Jugohrom had a production capacity of about 72,000 to 84,000 t/yr of 75%-grade ferrosilicon (Conway, 2016a).

**Malaysia.**—OM Materials Sarawak SDN BHD, the only ferrosilicon producer in Malaysia, increased its production to 126,261 t in 2016 compared with 46,832 t in 2015. This followed the completed construction of its ferrosilicon and manganese-alloy smelter at the end of 2015 (OM Holdings Ltd., 2017).

**Norway.**—In December, Norway's Competition Authority approved Elkem AS's purchase of ferrosilicon producer Fesil Rana Metall AS (Elkem AS, 2016). Prior to the acquisition of Fesil, Elkem had a ferrosilicon production capacity of 240,000 t/yr; the purchase of Fesil, which was renamed Elkem Rana AS, added an additional capacity of 80,000 t/yr of ferrosilicon (Metal-Pages, 2016c).

**Russia.**—Russia exported 447,000 t of ferrosilicon in 2016, 4% less than the 466,000 t exported in 2015. Russia imported 14,400 t of ferrosilicon, 22% less than the 18,400 t imported in 2015. Ferrosilicon, greater than 55% silicon grade, exported to Japan represented 34% of the total amount of ferrosilicon exported by Russia in 2016 (TEX Report, The, 2017a, b).

**South Africa.**—Ferroglöbe PLC operations in South Africa experienced a 17% decrease in silicon metal sales volumes owing to a decrease in exports to North America and a 19% decrease in silicon-base alloy sales volumes owing to a weak domestic market (Ferroglöbe PLC, 2017, p. 68). Ferroglöbe's three operations in South Africa have a combined production capacity of about 85,000 t/yr of ferrosilicon and 67,000 t/yr of silicon metal (Ferroglöbe PLC, 2016, p. 4).

**Ukraine.**—Zaporozhye Ferroalloy Plant increased its ferrosilicon production to more than 100,000 t in 2016 by reducing its manganese alloys and metal production to compensate for the closure of Privat Group's Stakhanov Ferroalloys Plant (Metal-Pages, 2017). Stakhanov had been the leading producer of ferrosilicon in Ukraine, with approximately 120,000 t of ferrosilicon produced in 2013, its last full year of production (Sparks, 2015). The plant closed in August 2014 because of the fighting in the Lugansk region.

**Venezuela.**—Ferroglöbe PLC idled their operation FerroAtlántica de Venezuela, S.A. (FerroVen) owing to market conditions and social and political instability in Venezuela. FerroVen sales in 2016 were \$30.4 million, a 57% decrease from 2015 sales of about \$70 million (Ferroglöbe PLC, 2017, p. 62, 69).

## 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 2016 USGS Minerals Yearbook, volume I, Metals and Minerals.

According to the World Steel Association (2017a), global crude steel production in 2016 was 1.63 billion metric tons (Gt) compared with 1.62 Gt in 2015. China, the world's leading producer of raw steel, produced 808.4 Mt in 2016, a slight increase from the 803.8 Mt produced in 2015. U.S. crude steel production in 2016 was 78.5 Mt, also essentially unchanged compared with the 78.8 Mt produced in 2015. World apparent consumption of finished steel products increased slightly to 1.52 Gt in 2016. China, the leading world consumer of steel products, increased consumption slightly to 681 Mt in 2016 from 672 Mt in 2015. The combined steel consumption in China, India, Japan, the Republic of Korea, and the United States increased slightly to 975 Mt from 967 Mt; these five countries accounted for about 64% of the world total in 2016. The World Steel Association's short-range forecast for global steel demand was 1.535 Gt in 2017 and 1.549 Gt in 2018 (World Steel Association, 2017b).

Consumption for silicon metal comes primarily from the aluminum and chemical industries. Ferroglöbe estimated world silicon metal consumption to be divided between the silicone (50%), aluminum (40%), and solar (10%) markets (Ferroglöbe PLC, 2016, p. 27–29). Global consumption of silicones was forecast to increase 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 2.6% annual growth from 2016 to 2019 and long-term annual growth rate of 1.3% from 2016 to 2025 in domestic aluminum casting sales (Modern Casting, 2017, p. 23).



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 predominately for solar-grade and semiconductor end uses.

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## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

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

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TABLE 1  
SALIENT SILICON STATISTICS<sup>1</sup>

(Contained silicon, unless otherwise noted)

	2012	2013	2014	2015	2016
United States:					
Production:					
Ferrosilicon	thousand metric tons	W	W	W	W
Silicon metal <sup>2</sup>	do.	W	W	W	W
Total silicon materials <sup>3</sup>	do.	390	392	401	411
Exports:					
Ferrosilicon	do.	12	10	9	9
Silicon metal	do.	75	38	45	37
Imports for consumption:					
Ferrosilicon	do.	175	157	186	162
Silicon metal	do.	136	118	139	140
Apparent consumption:					
Ferrosilicon	do.	W	W	W	W
Silicon metal <sup>2</sup>	do.	W	W	W	W
Total silicon materials <sup>3</sup>	do.	607	631	670	661
Price, average:					
Ferrosilicon, 50% Si <sup>4</sup>	cents per pound	100.44	102.56	107.81	101.19
Ferrosilicon, 75% Si <sup>5</sup>	do.	91.66	94.27	98.35	88.11
Silicon metal <sup>5</sup>	do.	127.34	122.39	140.39	126.63
World, production, gross weight:					
Ferrosilicon <sup>6</sup>	thousand metric tons	8,190 <sup>r</sup>	8,520 <sup>r</sup>	8,020 <sup>r</sup>	7,350 <sup>r</sup>
Silicon metal <sup>7</sup>	do.	1,770	2,060	2,320 <sup>r</sup>	2,550 <sup>r</sup>
Total silicon materials <sup>3,8</sup>	do.	10,300 <sup>r</sup>	10,900 <sup>r</sup>	10,700	10,200 <sup>r</sup>

<sup>r</sup>Revised. do. Ditto. W Withheld to avoid disclosing company proprietary data.

<sup>1</sup>Table includes data available through August 29, 2017. Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

<sup>2</sup>Does not include semiconductor and solar grades of silicon metals.

<sup>3</sup>Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal, excluding semiconductor and solar grades.

<sup>4</sup>CRU Group transaction prices based on weekly averages.

<sup>5</sup>S&P Global Platts mean import prices based on monthly averages.

<sup>6</sup>Does not include net production of ferrosilicon in the United States.

<sup>7</sup>Does not include net production of silicon metal in the United States.

<sup>8</sup>Includes 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<sup>1,2</sup>

(Metric tons, gross weight)

	Gross production <sup>3</sup>	Net shipments	Producers' stocks, December 31
2015:			
Ferrosilicon	W	W	W
Silicon metal	W	W	W
Total silicon materials	514,000	318,000	45,100
2016:			
Ferrosilicon	W	W	W
Silicon metal	W	W	W
Total silicon materials	471,000	318,000	37,100

W Withheld to avoid disclosing company proprietary data.

<sup>1</sup>Table includes data available through August 29, 2017. Data are rounded to no more than three significant digits.

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

<sup>3</sup>Ferrosilicon 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 2016<sup>1</sup>

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

Do. Ditto.

<sup>1</sup>Silicon metal producers do not include semiconductor and solar-grade silicon manufacturers.

<sup>2</sup>A wholly owned subsidiary of Ferroglobe PLC.

<sup>3</sup>Owned by Rima Industrial S.A. and CleanTech, LLC.

<sup>4</sup>A joint venture between Ferroglobe PLC and Dow Corning Corp.

TABLE 4  
REPORTED CONSUMPTION, BY END USE, AND STOCKS OF SILICON FERROALLOYS AND METAL IN THE  
UNITED STATES IN 2016<sup>1,2</sup>

(Metric tons, gross weight)

End use	Silvery pig iron <sup>3</sup>	Ferrosilicon, 50% <sup>4</sup>	Ferrosilicon, 75% <sup>5</sup>	Silicon metal <sup>6</sup>	Miscellaneous silicon alloys <sup>7</sup>	Silicon carbide <sup>8</sup>
Steel:						
Carbon and high-strength, low-alloy	W	38,900	32,200	(9)	(9)	(9)
Stainless and heat-resisting	--	(9)	44,200	(9)	(9)	(9)
Full alloy	--	(9)	8,710	(9)	(9)	--
Electric steel	--	--	(9)	--	--	(9)
Electric and tool	--	--	(9)	--	--	--
Unspecified	--	8,920	32,900	1,520	471	8,300
Total	--	47,800	118,000	1,520	471	8,300
Cast irons	W	18,300	21,000	(10)	12,100	18,700
Superalloys	--	--	(11)	115	--	--
Welding	--	(11)	--	(10)	--	--
Wear and corrosion	--	(11)	(11)	(10)	(12)	--
Aluminum	--	--	(11)	(10)	--	(12)
Copper	--	--	--	(10)	--	--
Nickel	--	--	(11)	(10)	(12)	--
Tungsten	--	--	--	(10)	--	--
Other alloys	--	(11)	--	--	(12)	--
Chemical carbides	--	--	--	--	(12)	--
Alloys, excluding superalloys and alloy steel	--	--	--	27,600 <sup>13</sup>	--	--
Miscellaneous and unspecified	--	231	608	W <sup>14</sup>	(12)	--
Grand total	W	66,400	140,000	W	12,500	27,000
Consumers' stocks, December 31	W	802	8,320	12,700	420	1,050

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

<sup>1</sup>Table includes data available through August 29, 2017. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Includes U.S. Geological Survey estimates.

<sup>3</sup>Typically 18% silicon content but ranges between 5% to 24% silicon content.

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

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

<sup>6</sup>Typically 98% silicon content but ranges between 96% to 99% silicon content.

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

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

<sup>9</sup>Included with "Steel: Unspecified," to avoid disclosing company proprietary data.

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

<sup>11</sup>Included with "Miscellaneous and unspecified," to avoid disclosing company proprietary data.

<sup>12</sup>Included with "Cast irons," to avoid disclosing company proprietary data.

<sup>13</sup>Primarily aluminum alloys.

<sup>14</sup>Primarily silicones and other chemicals.

TABLE 5  
U.S. EXPORTS OF FERROSILICON AND SILICON METAL IN 2016<sup>1,2</sup>

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
<b>Ferrosilicon:</b>			
<b>More than 55% silicon:</b>			
Brazil	45	27	\$85,600
Canada	1,390	836	2,170,000
Colombia	8	6	23,800
France	220	156	138,000
Hong Kong	4	2	6,000
Mexico	2,750	1,650	6,190,000
Singapore	9	6	19,900
Turkey	18	12	21,400
United Kingdom	223	162	176,000
<b>Total</b>	<b>4,670</b>	<b>2,860</b>	<b>8,840,000</b>
<b>Other ferrosilicon:</b>			
Belgium	529	242	676,000
Brazil	384	169	848,000
Canada	1,580	789	1,740,000
Japan	189	88	326,000
Korea, Republic of	720	316	768,000
Mexico	3,280	1,630	6,760,000
Netherlands	300	129	213,000
Thailand	220	100	414,000
Turkey	913	417	1,450,000
United Kingdom	200	92	337,000
Other (12 countries)	610	285	1,060,000
<b>Total</b>	<b>8,920</b>	<b>4,250</b>	<b>14,600,000</b>
<b>Total ferrosilicon</b>	<b>13,600</b>	<b>7,110</b>	<b>23,400,000</b>
<b>Metal:</b>			
<b>More than 99.99% silicon:</b>			
China	4,590	4,590	114,000,000
Germany	2,270	2,270	53,600,000
Hong Kong	4,790	4,790	37,500,000
Italy	236	236	7,240,000
Japan	21,500	21,500	947,000,000
Korea, Republic of	3,650	3,650	119,000,000
Malaysia	671	671	41,600,000
Norway	617	617	11,700,000
Taiwan	16,600	16,600	253,000,000
United Kingdom	314	314	12,300,000
Other (40 countries)	672	672	18,200,000
<b>Total</b>	<b>55,800</b>	<b>55,800</b>	<b>1,620,000,000</b>
<b>99.00–99.99% silicon:</b>			
Austria	40	40	56,800
Belgium	40	40	44,000
Brazil	22	22	54,600
Germany	323	320	817,000
Israel	12	12	17,600
Japan	30	30	42,200
Mexico	18	18	50,400
Netherlands	387	384	549,000
Singapore	70	70	99,200
United Kingdom	6	6	8,640
Other (4 countries)	9	9	18,700
<b>Total</b>	<b>958</b>	<b>950</b>	<b>1,760,000</b>
<b>Other silicon:</b>			
Belgium	1,480	1,440	1,660,000
Canada	463	449	1,010,000
China	102	98	156,000
France	55	54	62,100
Germany	41	40	69,500

See footnotes at end of table.



TABLE 5—Continued  
 U.S. EXPORTS OF FERROSILICON AND SILICON METAL IN 2016<sup>1,2</sup>

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
Metal:—Continued			
Other silicon:—Continued			
Japan	63	61	\$97,000
Mexico	213	207	344,000
South Africa	71	69	147,000
United Kingdom	240	234	422,000
Venezuela	55	53	72,300
Other (13 countries)	160	156	595,000
Total	2,940	2,860	4,630,000
Total silicon metal	59,700	59,600	1,620,000,000

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

<sup>2</sup>Table includes data available through August 29, 2017. Data 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 2016<sup>1,2</sup>

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
<b>Ferrosilicon:</b>			
55%–80% silicon, more than 3% Ca:			
Argentina	832	634	\$703,000
Brazil	4,550	3,440	4,510,000
China	1,120	844	1,030,000
France	643	394	1,850,000
Hong Kong	99	74	108,000
South Africa	1,580	1,110	3,770,000
Vietnam	79	59	77,000
Total	8,900	6,550	12,100,000
55%–80% silicon, other:			
Brazil	27,500	20,700	25,300,000
Canada	13,800	10,100	27,200,000
China	11,900	8,680	11,600,000
Iceland	19,400	14,700	18,200,000
Ireland	1,500	1,120	1,280,000
Malaysia	3,620	2,680	3,600,000
Netherlands	14,800	11,400	13,700,000
Norway	5,060	3,880	4,870,000
Russia	53,300	40,800	51,000,000
Venezuela	22,200	16,600	22,000,000
Other (8 countries)	3,570	2,550	9,370,000
Total	177,000	133,000	188,000,000
80%–90% ferrosilicon, Germany	115	95	150,000
More than 90% ferrosilicon:			
Brazil	2,600	2,450	1,250,000
China	40	35	26,700
Total	2,640	2,490	1,280,000
Magnesium ferrosilicon:			
Argentina	984	455	407,000
Canada	13,800	6,240	25,600,000
China	292	134	416,000
France	47	19	125,000
Germany	152	67	190,000
India	899	291	1,400,000
Norway	847	398	1,590,000
Total	17,000	7,610	29,800,000
Other ferrosilicon:			
Australia	6	1	5,670
Canada	10,300	3,690	11,300,000
China	6,190	1,260	2,700,000
France	28	13	90,700
Germany	80	33	219,000
India	47	18	123,000
Italy	20	3	26,500
Russia	90	44	136,000
Singapore	86	38	46,700
Slovakia	58	20	77,300
Other (3 countries)	10	4	14,700
Total	16,900	5,120	14,700,000
Total ferrosilicon	222,000	155,000	246,000,000
<b>Metal:</b>			
More than 99.99% silicon:			
Brazil	6,080	6,080	39,700,000
China	106	106	7,660,000
Germany	1,390	1,390	49,100,000
Japan	149	149	8,660,000
Korea, Republic of	208	208	5,000,000

See footnotes at end of table.

TABLE 6—Continued  
 U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL  
 IN 2016<sup>1,2</sup>

(Metric tons, unless otherwise specified)

Country or locality	Gross weight	Contained weight	Value
Metal:—Continued			
More than 99.99% silicon:—Continued			
Norway	21	21	\$155,000
Poland	17	17	39,800
Taiwan	196	196	4,580,000
Ukraine	5	5	315,000
United Kingdom	14	14	81,500
Other (11 countries)	10	10	2,170,000
Total	8,200	8,200	117,000,000
99.00%–99.99% silicon:			
Australia	16,300	16,200	32,900,000
Brazil	17,100	17,000	39,700,000
Canada	18,000	17,900	48,000,000
France	900	894	2,420,000
Kazakhstan	8,470	8,430	15,200,000
Laos	2,880	2,860	6,500,000
Malaysia	650	647	1,240,000
Norway	5,530	5,490	16,000,000
South Africa	21,200	21,100	51,900,000
Thailand	624	618	1,020,000
Other (9 countries)	300	285	694,000
Total	92,100	91,400	216,000,000
Other silicon:			
Australia	528	520	1,000,000
Bhutan	1,840	1,810	3,590,000
Brazil	8,420	8,260	20,300,000
Canada	1,680	1,640	3,780,000
China	316	308	412,000
Germany	307	294	360,000
Kazakhstan	1,080	1,040	2,240,000
Norway	6,860	6,690	10,200,000
South Africa	934	900	2,910,000
Sweden	230	221	251,000
Other (9 countries)	587	571	1,160,000
Total	22,800	22,300	46,200,000
Total silicon metal	123,000	122,000	379,000,000

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

<sup>2</sup>Table includes data available through August 29, 2017. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 7  
FERROSILICON AND SILICON METAL: WORLD PRODUCTION, BY COUNTRY OR LOCALITY<sup>1</sup>

(Metric tons, gross weight)

Country or locality <sup>2</sup>	2012	2013	2014	2015	2016
Argentina, ferrosilicon <sup>c</sup>	14,000	15,000	17,000	12,700	12,000
Australia, silicon metal <sup>e</sup>	30,000	30,000	48,000	48,000	48,000
Bhutan, ferrosilicon <sup>3</sup>	82,091 <sup>r</sup>	82,992 <sup>r</sup>	79,485 <sup>r</sup>	104,406 <sup>r</sup>	106,036
Bosnia and Herzegovina, silicon metal	15,874 <sup>r</sup>	16,707 <sup>r</sup>	18,383 <sup>r</sup>	18,716 <sup>r</sup>	18,700 <sup>e</sup>
Brazil: <sup>e</sup>					
Ferrosilicon	145,000	147,000	98,000	88,300 <sup>r</sup>	62,300
Silicon metal	133,000	134,000 <sup>r</sup>	92,300	70,000	70,000
Canada:					
Ferrosilicon	31,979	38,871	32,000 <sup>e</sup>	38,000 <sup>e</sup>	38,000 <sup>e</sup>
Silicon metal <sup>e</sup>	30,000	12,000	30,000	30,000	27,000
China: <sup>e</sup>					
Ferrosilicon	5,760,000	5,940,000 <sup>r</sup>	5,500,000	4,730,000	4,300,000
Silicon metal	1,140,000 <sup>r</sup>	1,450,000	1,710,000 <sup>r</sup>	1,950,000	2,200,000
Egypt, ferrosilicon <sup>4</sup>	55,300 <sup>e</sup>	50,800 <sup>e</sup>	56,794 <sup>r</sup>	56,093 <sup>r</sup>	56,000 <sup>e</sup>
France: <sup>e</sup>					
Ferrosilicon	63,000 <sup>r</sup>	50,000 <sup>r</sup>	50,000 <sup>r</sup>	35,000	35,000
Silicon metal	95,200	100,000	100,000	100,000	100,000
Germany, silicon metal <sup>e</sup>	29,000	28,000 <sup>r</sup>	28,000	30,000	30,000
Iceland, ferrosilicon	131,818	125,204	109,739 <sup>r</sup>	121,556 <sup>r</sup>	122,000 <sup>e</sup>
India, ferrosilicon <sup>4</sup>	90,000	92,013	92,014	92,000	90,000
Kazakhstan:					
Ferrosilicon	494	472	395 <sup>r</sup>	86,984 <sup>r</sup>	58,000 <sup>e</sup>
Silicon metal	5,000 <sup>r,e</sup>	5,000 <sup>r,e</sup>	998 <sup>r</sup>	866 <sup>r</sup>	-- <sup>e</sup>
Laos, silicon metal <sup>5</sup>	15,301 <sup>r</sup>	12,472 <sup>r</sup>	9,503 <sup>r</sup>	5,673 <sup>r</sup>	6,499
Macedonia, ferrosilicon	42,402	72,279	73,014	45,698	36,000 <sup>e</sup>
Malaysia, ferrosilicon	--	--	8,641	46,832 <sup>r</sup>	126,261
Norway:					
Ferrosilicon	250,000 <sup>e</sup>	349,389	350,000 <sup>e</sup>	350,000 <sup>e</sup>	350,000 <sup>e</sup>
Silicon metal <sup>e</sup>	150,000	150,000	150,000	150,000	150,000
Poland, ferrosilicon	78,115	73,589 <sup>r</sup>	62,878 <sup>r</sup>	77,138 <sup>r</sup>	77,000 <sup>e</sup>
Russia:					
Ferrosilicon	1,036,930	1,012,740	1,026,190	1,059,000	1,060,000 <sup>e</sup>
Silicon metal	52,500	55,000 <sup>e</sup>	60,000 <sup>e</sup>	60,000 <sup>e</sup>	59,300
Slovakia, ferrosilicon	36,869	41,664	47,019 <sup>r</sup>	45,961 <sup>r</sup>	46,000 <sup>e</sup>
South Africa:					
Ferrosilicon	83,100 <sup>r</sup>	78,400	87,700 <sup>r</sup>	87,700 <sup>r,e</sup>	71,200 <sup>e</sup>
Silicon metal	53,000	34,100 <sup>r</sup>	47,200 <sup>r</sup>	47,200 <sup>r,e</sup>	39,100 <sup>e</sup>
Spain: <sup>e</sup>					
Ferrosilicon	68,600	80,500	80,500	80,000	80,000
Silicon metal	27,200	29,200	29,200	30,000	30,000
Turkey, ferrosilicon <sup>e</sup>	2,000	2,000	2,000 <sup>r</sup>	2,000 <sup>r</sup>	2,000
Ukraine, ferrosilicon	150,265	191,207	167,977 <sup>r</sup>	114,826 <sup>r</sup>	101,100
United States:					
Ferrosilicon	W	W	W	W	W
Silicon metal	W	W	W	W	W
Total, silicon materials <sup>6</sup>	368,000	337,000	361,000	325,000	310,000
Uzbekistan, silicon metal <sup>e</sup>	1,700	6,000	5,000 <sup>r</sup>	5,000 <sup>r</sup>	3,000
Venezuela, ferrosilicon <sup>e</sup>	72,300	74,300	74,300	74,300	37,000
Grand total <sup>6</sup>	10,300,000 <sup>r</sup>	10,900,000 <sup>r</sup>	10,700,000	10,200,000 <sup>r</sup>	9,960,000
Of which:					
Ferrosilicon <sup>7</sup>	8,190,000 <sup>r</sup>	8,520,000 <sup>r</sup>	8,020,000 <sup>r</sup>	7,350,000 <sup>r</sup>	6,870,000
Silicon metal <sup>8</sup>	1,770,000	2,060,000	2,320,000 <sup>r</sup>	2,550,000 <sup>r</sup>	2,780,000
U.S. total, silicon materials <sup>6</sup>	368,000	337,000	361,000	325,000	310,000

<sup>e</sup>Estimated. <sup>r</sup>Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

<sup>1</sup>Table includes data available through July 20, 2017. All data are reported unless otherwise noted. Totals, U.S., and estimated data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Iran and Uruguay are thought to have produced ferrosilicon and Thailand is thought to have produced silicon metal, but available information was inadequate to make reliable estimates of output.

<sup>3</sup>Imports received to all countries from Bhutan. Source: UN Comtrade.

<sup>4</sup>Reported on a fiscal year basis, with start dates as follows: Egypt, July 1; and India, April 1.

<sup>5</sup>Imports received to all countries from Laos. Source: UN Comtrade.

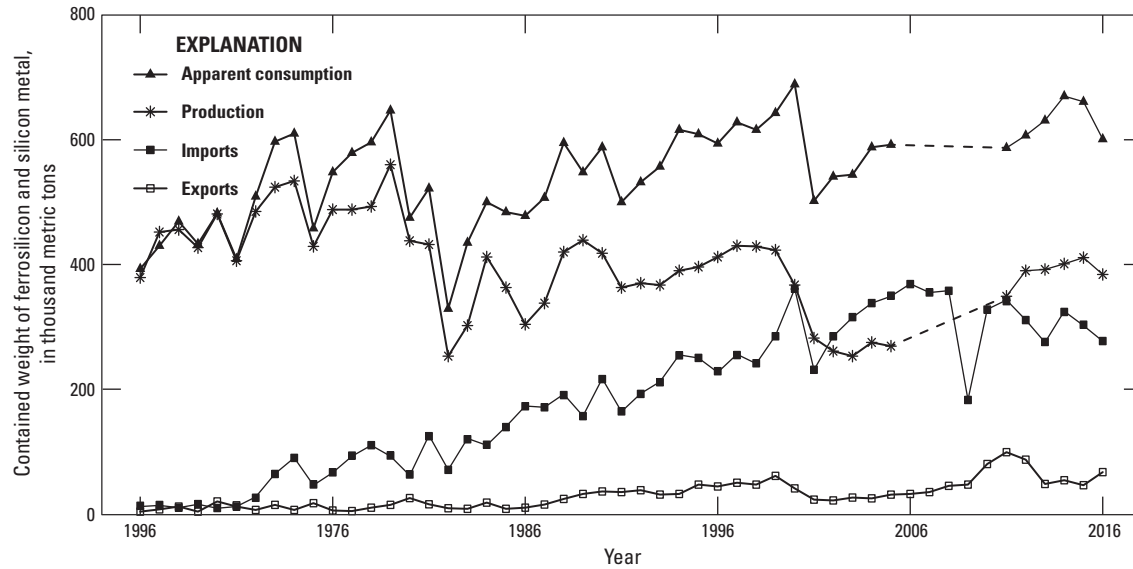
TABLE 7—Continued  
 FERROSILICON AND SILICON METAL: WORLD PRODUCTION, BY COUNTRY OR LOCALITY<sup>1</sup>

(Metric tons, gross weight)

<sup>6</sup>Includes total U.S. net production of ferrosilicon and silicon metal.

<sup>7</sup>Does not include total U.S. net production of ferrosilicon.

<sup>8</sup>Does not include total U.S. net production of silicon metal.



**Figure 1.** Gross production, imports and exports, and apparent consumption of ferrosilicon and silicon metal (contained silicon) in the United States from 1966 through 2016. 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, U.S. Geological Survey.