GALLIUM

(Data in kilograms of gallium content unless otherwise noted)

Domestic Production and Use: No domestic primary (low-grade, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in Utah recovered and refined high-purity gallium from imported low-grade primary gallium metal and new scrap. Imports of gallium were valued at about $9 million. Gallium arsenide (GaAs) and gallium nitride (GaN) wafers used in integrated circuits (ICs) and optoelectronic devices accounted for approximately 75% of domestic gallium consumption. Production of trimethyl gallium and triethyl gallium, metalorganic sources of gallium used in the epitaxial layering process for the production of light-emitting diodes (LEDs), accounted for most of the remainder. About 57% of the gallium consumed was used in ICs. Optoelectronic devices, which include laser diodes, LEDs, photodetectors, and solar cells, accounted for nearly all of the remaining gallium consumption. Optoelectronic devices were used in aerospace applications, consumer goods, industrial equipment, medical equipment, and telecommunications equipment. Uses of ICs included defense applications, high-performance computers, and telecommunications equipment.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, primary	—	—	—	—	—
Imports for consumption	85,700	58,200	35,400	53,900	32,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	35,300	34,400	37,800	35,800	36,000
Price, yearend, dollars per kilogram[1]	688	529	502	363	295
Stocks, consumer, yearend	6,850	6,220	5,470	3,980	3,000
Net import reliance[2] as a percentage of reported consumption	100	100	100	100	100

Recycling: Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in Utah.

Import Sources (2011–14): Germany, 35%; China, 26%; United Kingdom, 22%; Ukraine, 9%; and other, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Gallium arsenide wafers, undoped	2853.00.0010	2.8% ad val.
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3.0% ad val.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. Gallium prices decreased throughout 2015, continuing the more than 3-year decline, as significant increases in China's low-grade (99.99%-pure) primary gallium production continued to exceed increases in worldwide consumption. In January, the price for low-grade gallium in Asia averaged $195 per kilogram. By October, the price had decreased to $140 per kilogram. China's low-grade primary gallium production capacity has expanded tremendously to approximately 600 metric tons per year in 2015 from 140 metric tons per year in 2010 on the expectations of increases in LED-based backlighting and general lighting demand. China accounted for 83% of worldwide low-grade gallium capacity.

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GALLIUM

Owing to their large power-handling capabilities, high-switching frequencies, and higher-voltage capabilities, GaN-based products, which historically have been used in defense and military applications, have begun to gain acceptance in cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets. In 2015, the GaN radio frequency device market was valued at about $250 million, a 22% increase from that of 2014, and was forecast to increase at an average annual rate of 22% to reach $560 million in 2019.

Global demand for GaAs- and GaN-based products increased in 2015. GaAs device consumption increased by about 6% to $7 billion owing to a growing wireless infrastructure in Asia; growth of feature-rich, application-intensive, third- and fourth-generation "smartphones," which employ up to 10 times the amount of GaAs as standard cellular handsets; and robust use in military radar and communications applications. In 2015, approximately 1.5 billion smartphones were sold worldwide, a 16% increase from that of 2014. Smartphones were estimated to account for 75% of all worldwide cellular telephone sales.

During the last several years, significant expansion of LED manufacturing capacity in Asia took place, much of it owing to China's Government-instituted incentives to increase LED production, and LED production costs and prices have declined. Owing to overproduction, only 22% of the LED chips produced in 2015 were consumed. General lighting became the largest sector among LED applications, surpassing television backlighting in 2014, and was expected to be the major driver of the LED market for the rest of the decade. The LED market, valued at $15.6 billion in 2014, was forecast to increase at an average annual rate of 7% to reach $22 billion in 2019.

World Production and Reserves:[3] In 2015, world low-grade primary gallium production was estimated to be 435 metric tons—about the same as production in 2014. Some low-grade primary gallium producers most likely restricted output owing to a large surplus of primary gallium. China, Germany, Japan, and Ukraine were the leading producers; countries with lesser output were Hungary, the Republic of Korea, and Russia. Kazakhstan, which had been a leading producer in 2012, did not produce any low-grade primary gallium in 2013, and most likely did not produce any in 2014 and 2015. Refined high-purity gallium production (from low-grade primary sources only, not recycled) in 2015 was estimated to be about 160 metric tons. China, Japan, the United Kingdom, the United States, and possibly Slovakia were the principal producers of high-purity refined gallium. Gallium was recycled from new scrap in Canada, Germany, Japan, the United Kingdom, and the United States. World low-grade primary gallium production capacity in 2015 was estimated to be 730 metric tons per year; high-purity refinery capacity, 230 metric tons per year; and secondary capacity, 200 metric tons per year.

Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of treating bauxite, and the remainder is produced from zinc-processing residues. Only part of the gallium present in bauxite and zinc ores is recoverable, and the factors controlling the recovery are proprietary. Therefore, an estimate of reserves is not practicable.

World Resources: The average gallium content of bauxite is 50 parts per million (ppm). U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Recovery of gallium from these deposits is therefore unlikely. Some domestic zinc ores contain as much as 50 ppm gallium and could be a significant resource, although no gallium is currently recovered from domestic ore. Gallium contained in world resources of bauxite is estimated to exceed 1 million metric tons, and a considerable quantity could be contained in world zinc resources. However, only a small percentage of the gallium in bauxite and zinc resources is potentially recoverable.

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier 3G cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. GaAs-based ICs are used in many defense-related applications because of their unique properties, and no effective substitutes exist for GaAs in these applications. GaAs in heterojunction bipolar transistors is being challenged in some applications by silicon-germanium.

[e]Estimated. NA Not available. — Zero.
[1]Estimated based on the average values of U.S. imports for 99.9999%- and 99.99999%-pure gallium.
[2]The United States has not produced gallium since 1987 and recovers no gallium from old scrap. All domestic consumption is assumed to originate from imported gallium.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: Garnet for industrial use was mined in 2015 by four firms—one in Idaho, one in Montana, and two in New York. The estimated value of crude garnet production was about $5.79 million, and refined material sold or used had an estimated value of $9.33 million. Major end uses for garnet were: waterjet cutting, 35%; abrasive blasting media, 30%; water filtration, 20%; abrasive powders, 10%; and other end uses, 5%. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production (crude)	56,400	46,900	33,900	32,200	34,000
Production (refined, sold or used)	33,700	25,800	32,600	30,900	32,700
Imports for consumption[e]	154,000	222,000	197,000	213,000	266,000
Exports[e]	14,500	14,600	14,400	15,500	15,200
Consumption, apparent[e, 2]	196,000	254,000	216,000	230,000	285,000
Employment, mine and mill, number[e]	160	160	160	150	150
Net import reliance[3] as a percentage of apparent consumption	71	82	84	86	88

Recycling: Small quantities of garnet reportedly are recycled.

Import Sources (2011–14):[e] Australia, 46%; India, 38%; China, 8%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Emery, natural corundum, natural garnet, and other natural abrasives, crude	2513.20.1000	Free.
Emery, natural corundum, natural garnet, and other natural abrasives, other than crude	2513.20.9000	Free.
Natural abrasives on woven textile	6805.10.0000	Free.
Natural abrasives on paper or paperboard	6805.20.0000	Free.
Natural abrasives sheets, strips, disks, belts, sleeves, or similar form	6805.30.1000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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