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2009 Minerals Yearbook

GALLIUM

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GALLIUM

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In 2009, no domestic production of primary gallium was reported and gallium metal and gallium arsenide (GaAs) wafer imports continued to account for most of the U.S. gallium consumption. Metal imports were 13% lower than those in 2008, with Canada, Germany, the United Kingdom, and China, in descending order of imports by gallium content, as the leading sources of imported gallium. Doped GaAs wafer imports were 29% lower than those in 2008; Germany and Japan were the principal sources. Almost all gallium consumed in the United States was in the form of GaAs and gallium nitride (GaN) and was used in integrated circuits (ICs) and optoelectronic devices [laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells]. Gallium consumption decreased by 13% from that in 2008. In 2009, gallium consumed in the United States was less than the gallium imported because a large portion of the U.S. imports was estimated to be low-purity material that was refined in the United States and shipped to other countries.

In 2009, estimated world crude gallium production was 79 metric tons (t), 29% lower than that in 2008. Principal producers were China, Germany, Kazakhstan, Russia, and Ukraine. Plants in Hungary, Japan, and Slovakia also recovered gallium. Refined gallium production was estimated to be about 122 t, which included some new scrap refining. Refined gallium was produced in China, Japan, the United Kingdom, and the United States.

Legislation and Government Programs

The U.S. Department of Energy (DOE) awarded $6.4 million to four research projects focused on improving green LEDs and organic blue emitters. Of the total, $4.6 million was provided via the American Recovery and Reinvestment Act (ARRA). These projects continued the DOE's effort to advance state-of-the-art solid-state lighting (SSL) used for general lighting applications. The award recipients included the National Renewable Energy Laboratory, the Pacific Northwest National Laboratory, Sandia National Laboratories, and the U.S. Army Laboratory (Semiconductor Today, 2009i). The DOE also announced that $50 million of ARRA funding had been allocated for additional SSL research and development (LEDs Magazine, 2009b).

Northrop Grumman Corp. (Los Angeles, CA) and TriQuint Semiconductor, Inc. (Hillsboro, OR) were respectively awarded $28.9 million and $16.2 million Defense Advanced Research Projects Agency (DARPA) multiyear contracts to create high-dynamic-range digital GaN circuits for future defense and aerospace applications. The contracts support the first phase of DARPA's Nitride Electronic NeXt-Generation Technology (NEXT) program. Digital GaN circuits, unlike analog GaN circuits, have the potential to increase operating frequencies while simultaneously employing very high breakdown voltages. The NEXT circuit design was expected to lead to dramatic improvements in the performance of radio frequency (RF) and mixed-signal electronic circuits and was expected to fundamentally improve performance in U.S. military and space applications (Northrop Grumman Corp., 2009; TriQuint Semiconductor, Inc., 2009).

Production

No domestic production of primary gallium was reported in 2009 (table 1). Recapture Metals Inc. (Blanding, UT) recovered gallium from scrap materials, predominantly those generated during the production of GaAs. Recapture Metals' facilities have the capability to produce about 40 metric tons per year (t/yr) of high-purity gallium. The company recovered gallium from its customers' scrap on a fee basis and purchased scrap and low-purity gallium for processing into high-purity material.

In August, Recapture Metals was acquired by Neo Performance Materials Ltd. (Toronto, Ontario, Canada), a producer and processor of magnetic powders, and rare earth and zirconium-based engineered materials. As a wholly owned subsidiary of Neo Performance Materials, Recapture Metals retained its name (Metal-Pages, 2009b).

Consumption

Gallium consumption data were collected by the U.S. Geological Survey from a voluntary survey of U.S. operations. In 2009, there were 11 respondents to the consumption of gallium survey, representing 61% of the total canvassed. Data in tables 2 and 3 were adjusted by incorporating estimates to reflect full industry coverage. Many of these estimates were based on company 2009 10–K reports submitted to the U.S. Securities and Exchange Commission.

More than 99% of the gallium consumed in the United States was in the form of GaAs or GaN. GaAs was used to manufacture optoelectronic devices (laser diodes, LEDs, photodetectors, and solar cells) and ICs. ICs accounted for 74% of domestic consumption, optoelectronic devices accounted for 25%, and 1% was used in research and development and other applications (table 2). GaN principally was used to manufacture LEDs and laser diodes.

In 2009, U.S. consumption of gallium for use in ICs was not significantly affected by the global economic downturn and remained relatively flat compared with that of 2008. Gallium use in LEDs and laser diodes increased by 41% from that of 2008 owing to the exceptional growth in demand from the LED industry beginning in the third quarter of 2009. Gallium suppliers to the photodetector and solar cell industry were affected in 2009 by the economic downturn. U.S. gallium consumption decreased by 83% compared with that of 2008, as photodetector and solar cell customers did not restock in 2009.

Gallium Arsenide.—In 2009, the value of worldwide GaAs device consumption remained approximately flat compared with that of 2008 at $3.7 billion. Following a 5% decline in consumption during the first half of 2009, the GaAs device market rebounded strongly in the second half of the year owing to the strong growth of GaAs-rich third-generation (3G) and fourth-generation (4G) “smartphones” (cellular telephones with advanced personal computer-like functionality). These devices use up to four times the amount of GaAs of previous generations of cellular telephones. In 2009, smartphone market sales increased by 15% from those of 2008 (Bernhardt, 2010; Semiconductor Today, 2010b).

Sumika Electronic Materials Inc. (Phoenix, AZ) met increasing GaAs epiwafer demand by increasing production capacity of its Phoenix GaAs epiwafer foundry with the installation of an additional Aixtron 2600 G3 epi reactor (Sumika Electronic Materials Inc., 2009).

To also meet growing GaAs wafer demand, EpiWorks Inc. (Champaign-Urbana, IL) announced plans to increase its 6-inch GaAs wafer production capacity to 100,000 wafers per year by yearend 2009. The company had previously boosted its 6-inch wafer production capacity to 50,000 wafers per year in 2007 (Semiconductor Today, 2009d).

Gallium Nitride.—Increased demand for GaN device applications, namely laser diodes, power electronics, and RF electronics, has provided significant growth opportunities for advanced GaN-based products. GaN power management applications, in particular, have shown much promise. GaN power transistors operate at higher voltages and with a higher power density than current GaAs devices. GaN power transistors and amplifiers have allowed microwave designers to reduce heat sink requirements and part counts, enabling smaller systems with higher performance and greater efficiency. The key drivers of this emerging GaN-based technology have been military and defense applications.

In September, scientists at the Massachusetts Institute of Technology (MIT) (Cambridge, MA) successfully integrated GaN with silicon to create a hybrid microchip that was expected to be smaller, faster, and more efficient than current silicon-based microprocessors. The MIT scientists anticipated that the new integration process would enable circuit and system designers to choose the best semiconductor material for each device in the microchip rather than having to compromise by using only one material for all the circuits (Savage, 2009).

In October, IQE plc (St. Mellons, United Kingdom) acquired United Kingdom-based GaN substrate firm NanoGaN Ltd. NanoGaN had previously established a range of processes and intellectual property relating to GaN materials and devices, including its proprietary nanocolumn technology for producing high quality, free-standing GaN substrates. The substrates were used in the manufacture of high-quality blue and green semiconductor lasers and ultrahigh brightness LEDs for SSL (Huang, 2009).

RF Micro Devices, Inc. (RFMD) opened its GaN foundry service in Greensboro, NC, and indicated that its GaN technology was to be targeted at high-power applications rather than lower-power, higher-frequency applications. The company’s GaN manufacturing technology was to be housed in the same facility as its GaAs products (Semiconductor Today, 2009g).

Collaboration between Aixtron AG of Aachen, Germany, and SemiLEDs Corp. of Boise, ID, resulted in successful fabrication of GaN-based blue LED chips on 6-inch sapphire wafers. Mass manufacturing capability of blue LEDs was previously limited to 2-inch and 4-inch wafers. Approximately 10,000 LED chips can be processed simultaneously on a 2-inch wafer, while 90,000 LED chips can be processed simultaneously on a 6-inch wafer, thereby offering potentially significant cost savings in the manufacture of blue LEDs (Semiconductor Today, 2009a).

Light-Emitting Diodes.—Despite the global economic downturn, the worldwide high-brightness (HB) LED market increased to $5.4 billion in 2009, a 6% increase from $5.1 billion in 2008. HB LEDs experienced record growth in the second half of 2009 as a result of the rapid shift to LEDs in computer notebook displays and liquid crystal display (LCD) televisions using LED-based backlighting. LED-based backlighting allows for lighter and thinner screens, higher color saturation, and lower power consumption compared with traditional cold-cathode fluorescent lamp backlighting sources. Research and consulting firm IMS Research indicated that 46% of all computer notebooks rapidly shifted to LEDs in 2009, up from only 6% in 2008. Approximately 3% of all LCD televisions used LED backlighting in 2009, up from virtually none in 2008 (Semiconductor Today, 2009f, 2010c; Young, 2010).

In addition to LED-based backlighting applications, many general lighting projects were also addressed by LED lighting, including installations in hotels and casinos, municipal lighting, parking garages, and retail establishments. LED lighting allowed for greater energy efficiency, longer lifespan, and improved quality of light (Steele, 2010).

Research and consulting firm Strategy Analytics Inc. listed the main global segments for LEDs in 2009 as follows: signage, displays, and signaling, 37%; cellular and other mobile appliances, 30%; general illumination, 22%; automotive, 8%; and front-projection television and other backlighting, 3% (Young and Low, 2009). Total worldwide consumption of LEDs rose by 10.5% to 63 billion units in 2009 from 57 billion units in 2008. LED consumption in 2009 approached the industry’s total capacity of 75 billion units, an 84% utilization rate (Semiconductor Today, 2010e).

LED firms began expanding their manufacturing capacities in 2009 in response to the growing popularity of LED backlighting and general LED lighting applications. Semiconductor Equipment and Materials International (SEMI) of San Jose, CA, indicated that seven new LED fabrication plants came online in 2009. SEMI announced that the region with the greatest number of LED fabrication plants was Taiwan (40%), followed by Japan (23%), and China (22%) (Semiconductor Today, 2010d).

Solar Cells.—Sustained high energy prices continued to spark interest in solar energy. Most of the solar cells that were manufactured for terrestrial applications were thin-film multijunction cells, with a substrate of germanium and layers of gallium indium arsenide and other gallium compounds. A lightweight, flexible, durable, and low-cost thin-film photovoltaic technology, copper indium gallium selenide (CIGS), has recently entered the printed solar cell market. CIGS modules can be directly integrated into building materials, consumer electronics for portable power, space applications, or configured as stand-alone modules for large-scale terrestrial deployment.

Research and consulting firm Displaybank Co., Ltd. (Bundang, Republic of Korea) reported that CIGS was the fastest growing technology within the printed solar cell market. In 2009, the worldwide CIGS market was valued at $96 million and increased by 81% from that of 2008. In 2010, the worldwide CIGS market was estimated to grow to $240 million, a 150% increase from that of 2009 (Displaybank Co., Ltd., 2009).

Several records for solar cell efficiency were achieved in 2009. Spectrolab Inc. (Sylmar, CA) (a wholly owned subsidiary of The Boeing Co.) set a world record for terrestrial concentrator solar cell efficiency with a photovoltaic device that converted greater than 41% of the light that hit it into electricity. The solar cell incorporated improvements in wafer processing that raised the cell's overall efficiency. Additionally, Global Solar Energy Inc. (Tucson, AZ) achieved a record 15.45% efficiency for its CIGS thin film solar cell. The company's CIGS material used a flexible substrate that allowed it to be lightweight, flexible, and durable, unlike traditional solar panels which tend to be heavy, rigid, and fragile. Both solar cell efficiency records were verified by the DOE's National Renewable Energy Laboratory (Boeing Co., The, 2009; Metal-Pages, 2009a).

In September, Solyndra Inc. (Fremont, CA) began construction of its second CIGS photovoltaic panel manufacturing plant. The plant was designed for an annual production capacity of 500 megawatts (MW) and was scheduled to open in late 2010. Solyndra's photovoltaic system was engineered to generate considerably more solar electricity from conventional low-slope commercial rooftops while having lower installation costs than standard photovoltaic flat-panel technologies. The cylindrical shape allows sunlight to be captured across a 360° photovoltaic surface capable of converting direct, diffuse, and reflected sunlight into electricity. Conventional flat-surfaced solar panels typically offer poor collection of diffuse light and fail to collect reflected light from installation surfaces (Semiconductor Today, 2009b).

Prices

Since 2002, producer prices for gallium have not been quoted in trade journals. Data in table 4 represent the average customs value of gallium imported into the United States. Reports in Mining Journal indicated that low-grade gallium prices decreased in 2009. At the beginning of the year, the low-grade gallium price was reported to be about $450 per kilogram. By August, the price had decreased to about $400 per kilogram. By December, the price had decreased to about $350 per kilogram.

From U.S. Census Bureau import data, the annual average value for low-grade (99.99%-pure) gallium was estimated to be $304 per kilogram, 16% lower than the estimated average value for 2008. For high-grade (>99.99%-pure) gallium, the annual average estimated value decreased to $449 per kilogram, about 22% lower than that in 2008. Import data reported by the U.S. Census Bureau do not specify purity, so the values listed in table 4 were estimated based on the average value of the material imported and the country of origin.

Foreign Trade

In 2009, U.S. gallium imports were 13% lower than those in 2008 (table 5). Canada (29%), Germany (20%), the United Kingdom (19%), and China (17%) were the leading sources of imported gallium.

In addition to gallium metal, GaAs wafers were imported into the United States (table 6). In 2009, 28,300 kilograms (kg) of undoped GaAs wafers and 117,000 kg of doped GaAs wafers were imported. Imports of undoped GaAs wafers were significantly more than those in 2008, while imports of doped GaAs wafers were 29% less than those in 2008. The large volumes of undoped GaAs wafers were primarily imported from Canada and the United Kingdom. The large increase was most likely owing to intercompany transfers between foreign and the U.S. subsidiary of the same company. The data listed in table 6 may include some packaging material and, as a result, quantities may be higher than the actual total weight of imported wafers.

World Review

Imports of gallium into Japan and the United States, the two leading consuming countries, were used as the basis for estimating world gallium production. Estimated crude gallium production was 79 t in 2009. Principal world producers were China, Germany, Kazakhstan, Russia, and Ukraine. Gallium also was recovered in Hungary, Japan, and Slovakia. Refined gallium production was estimated to be about 122 t; this included some new scrap refining. China, Japan, the United Kingdom, and the United States refined gallium. Gallium was recycled from new scrap in Canada, Germany, Japan, the United Kingdom, and the United States.

China.—In August, MCP Group SA (Tilly, Belgium) announced that it had formed a joint venture with Chinese company Golden Harvest Ltd. to create an integrated gallium operation capable of producing both low-purity and high-purity gallium. The joint venture, named MCP Crystal, consisted of four operations—three 99.99% (4N) plants and one 6N and 7N plant. The 4N plants were expected to collectively produce between 70 t/yr and 80 t/yr of gallium. The plants were located in Henan, Shangxi, and Sichuan Provinces (Metal Bulletin, 2009).

In 2009, Aluminum Corp. of China Ltd. (Chalco) continued idling additional alumina refineries since the reduction of output first began in the last quarter of 2008 because of the deteriorating global economy and declining price of aluminum. By March, Chalco had cut alumina production by 4.1 million metric tons, equivalent to 38% of its alumina refining capacity. As the largest producer of byproduct gallium in China, Chalco's reduction in alumina production was expected to affect the worldwide supply of gallium (Ye, 2009).

Malaysia.—In December, Osram Opto Semiconductors (Munich, Germany) announced the completion of its second LED chip production plant, in Penang, Malaysia. The new facility augmented the company's main production facility in Regensburg, Germany. The new facility produced indium gallium nitride (InGaN)-based LED chips, fabricated on 4-inch wafers, which form the basis for the blue, green, and white LEDs used primarily in architecture, general lighting, and display backlighting in mobile terminal devices (LEDs Magazine, 2009c).

Taiwan.—In an effort to meet the growing demand for GaAs-based amplifiers, Kopin Corp. (Taunton, MA) announced in August that it had invested $6.3 million in its majority-owned Asian foundry venture, Kopin Taiwan Corp. to transition from 4-inch to 6-inch GaAs epiwafer production (Semiconductor Today, 2009e).

To meet the increasing demand for GaAs wafers, WIN Semiconductors Corp. of Taiwan opened the second of its

6-inch GaAs wafer fabrication plants. The new plant's capacity of 5,000 wafers per month (wpm) augments WIN's existing capacity of 7,000 wpm (Semiconductor Today, 2009h).

In December, Visual Photonics Epitaxy Co. of Taiwan announced plans to expand its GaAs wafer production capacity by 40% to 60% in 2010 by increasing the number of its metal-organic chemical vapor deposition (MOCVD) reactors to 30 from its current 22. The total expansion investment was expected to cost $18 million (Semiconductor Today, 2009c).

SemiLEDs Corp. opened a third high-power LED chip facility in Hsinchu Science Park, Taiwan. The new production facility increased SemiLEDs high-power LED chip production capacity to 15 million chips per month. LG Corp. (Seoul, Republic of Korea) planned to establish a new LCD glass panel and LED backlight production facility in Paju, Gyeonggi Province, Republic of Korea. The plant eventually would increase the company's LED production to four times its current capacity (LEDs Magazine, 2009a, d).

Outlook

According to IQE, "smartphones" represented a fundamental structural shift in mobile communications. Growth of smartphones, which on the average contain 480% more GaAs-rich RF content than standard cellular telephones, were expected to account for 19% of all handset sales in 2010, increasing to more than 50% by 2014. Installation of 3G and 4G mobile networks in India and the Republic of Korea were expected to aid the sales growth of smartphones further. Growth in GaAs demand will also be driven by new applications for wireless fidelity (WiFi) such as point-to-point communications, smart meters, and tablet personal computer technologies. Strategy Analytics predicted that the GaAs industry would grow at a compound annual growth rate of 5%, increasing to $4.7 billion by 2014, up from $3.7 billion in 2009 (Business Wire, 2010; IQE, plc, 2010).

Research and consulting firm iSuppli Corp. predicted the GaN power management market would reach $184 million in revenue by 2013, up from virtually zero in 2009. The firm indicated that two events—silicon reaching its practical limits in power management semiconductors and breakthroughs in growing GaN layers on silicon—favored GaN power management devices taking market share away from conventional metal oxide semiconductor field-effect transistors, driver ICs, and voltage regulator ICs. The GaN power management devices' improved efficiency and smaller size would be in high demand for portable electronic products as well as for power-hungry enterprise servers and wired communications infrastructure equipment (Shaw, 2010).

Strategy Analytics indicated that the U.S. defense industry would continue to be the driver for the RF and power management GaN microelectronics market. The firm expected military applications to represent nearly one-half of the estimated $380 million market by 2014 (Semiconductor Today, 2010a).

According to Strategies Unlimited, the HB LED market was expected to experience unprecedented growth opportunities during the next 5 years from general lighting applications and backlights for LCDs in computer monitors, notebook computers, and televisions. The firm forecast that the HB LED market would increase to $8.2 billion in 2010, a 52% increase from $5.4 billion in 2009, and projected the market to increase to $20.5 billion in 2014, growing at an average rate of 30.6% per year. The firm predicted LED unit volume growth of 44% in 2010, and forecast that by 2014 LED unit volume would be four times higher than that in 2009, exceeding 200 billion units. To meet the projected LED demand, Strategies Unlimited calculated that 200 additional MOCVD reactors would be needed by 2010 and another 280 reactors would be needed by 2011 (Steele, 2010).

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TABLE 1

SALIENT U.S. GALLIUM STATISTICS[1]

(Kilograms unless otherwise specified)

		2005	2006	2007	2008	2009
Production		--	--	--	--	--
Imports for consumption		15,800	26,900	37,100	41,100	35,900
Consumption		18,700	20,300	25,100	28,700	24,900
Price[2]	dollars per kilogram	538	443	530	579	449

-- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Estimate based on average value of U.S. imports of high-purity gallium.

TABLE 2

U.S. CONSUMPTION OF GALLIUM, BY END USE[1, 2]

(Kilograms)

End use	2008	2009
Optoelectronic devices:		
Laser diodes and light-emitting diodes	3,800	5,370
Photodetectors and solar cells	5,040	849
Integrated circuits:		
Analog	16,900	17,200
Digital	2,310	1,280
Research and development	497	135
Other	110	68
Total	28,700	24,900

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

[2]Includes gallium metal and gallium compounds.

TABLE 3

STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM, BY GRADE[1, 2]

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2008:				
99.99% to 99.999%	3,530	155	976	2,710
99.9999%	2,420	6,060	7,550	929
99.99999% to 99.999999%	51	622	500	173
Total	6,010	6,830	9,030	3,820
2009:				
99.99% to 99.999%	2,710	528	--	3,240
99.9999%	929	927	1,120	740
99.99999% to 99.999999%	173	383	438	118
Total	3,820	1,840	1,550	4,100

-- Zero.

[1]Consumers only.

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

TABLE 4

ESTIMATED AVERAGE GALLIUM PRICES

(Dollars per kilogram)

Gallium metal	2008	2009
Purity ≥ 99.9999%; average value of U.S. imports	579	449
Purity ≤ 99.99%; average value of U.S. imports	361	304

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF GALLIUM (UNWROUGHT, WASTE, AND SCRAP), BY COUNTRY[1]

	2008		2009	
Country	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Armenia	888	$396,000	--	--
Canada	10,200	6,130,000	10,500	$3,670,000
China	6,600	2,930,000	6,100	2,240,000
France	98	107,000	719	325,000
Germany	13,500	5,080,000	7,110	2,630,000
Hungary	1,410	639,000	--	--
Japan	616	548,000	915	504,000
Singapore	516	204,000	--	--
Ukraine	1,170	445,000	3,750	990,000
United Kingdom	5,930	1,950,000	6,740	2,170,000
Other	145 r	29,400 r	106	38,700
Total	41,100	18,500,000	35,900	12,600,000

[r]Revised. -- Zero.

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

[2]Customs value.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF GALLIUM ARSENIDE WAFERS, BY COUNTRY[1]

	2008		2009	
Material and country	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Undoped:				
Austria	94	$37,600	30	$16,000
Canada	--	--	15,800	2,480,000
France	250	48,800	--	--
Japan	112	12,600	72	3,600
Singapore	150	25,000	--	--
Taiwan	324	101,000	886	173,000
United Kingdom	18	3,800	11,500	21,900
Other	7 r	11,700 r	13	24,200
Total	955	241,000	28,300	2,720,000
Doped:				
China	20,800	19,500,000	5,680	10,200,000
Finland	12,600	6,030,000	1,370	1,410,000
France	2,810	6,480,000	1,630	4,290,000
Germany	34,100	33,500,000	29,500	18,200,000
Italy	2,330	352,000	6,120	196,000
Japan	60,900	54,000,000	52,800	57,000,000
Korea, Republic of	13,600	2,400,000	2,610	946,000
Malaysia	3,720	853,000	82	43,300
Singapore	2,180	5,180,000	6,430	10,100,000
Taiwan	7,860	22,000,000	7,560	22,000,000
United Kingdom	1,290	1,190,000	1,160	2,280,000
Other	2,580 r	3,690,000 r	2,050	1,790,000
Total	165,000	155,000,000	117,000	129,000,000

[r]Revised. -- Zero.

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

[2]Customs value.

Source: U.S. Census Bureau.

TABLE 7

ESTIMATED WORLD ANNUAL PRIMARY GALLIUM PRODUCTION CAPACITY, DECEMBER 31, 2009[1]

(Metric tons)

Country	Capacity
China	59
Germany	35
Hungary	8
Japan	20
Kazakhstan	25
Russia	19
Slovakia	8
Ukraine	10
Total	184

[1]Includes capacity at operating plants as well as at plants on standby basis.