



2016 Minerals Yearbook

RARE EARTHS [ADVANCE RELEASE]

RARE EARTHS

By Joseph Gambogi

Domestic survey data and tables were prepared by Annie Hwang, statistical assistant.

In 2016, world rare-earth mine production was 129,000 metric tons (t) of rare-earth oxide (REO) (tables 1, 6). China continued to dominate global production and consumption of rare-earth metals and compounds. Rare-earth mineral concentrates were produced in China, with smaller amounts produced in Australia, Brazil, India, Malaysia, Russia, Thailand, and Vietnam (table 6). The unique properties of rare earths make them useful in a wide variety of applications, such as alloys, batteries, catalysts, magnets, phosphors, and polishing compounds. In the United States, there was no production of rare-earth ores and concentrates. The rare-earth mining and processing operation in Mountain Pass, CA, remained on care-and-maintenance status. Prices for most rare-earth metals and compounds declined by more than 30% relative to those in 2015 (table 3).

The rare earths are a group of moderately abundant elements comprising the 15 lanthanides, scandium (Sc), and yttrium (Y). The lanthanides are the elements with atomic numbers 57 through 71, in order of atomic number: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). In rock-forming minerals, rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates (Mason and Moore, 1982, p. 46). The principal economic rare-earth minerals are bastnäsite, loparite, monazite, xenotime, and the lateritic ion-adsorption clays. The percentage distribution of REOs in mineral concentrates varied significantly based on mineral source and location (table 2).

Excluding scandium, a rare-earth element (REE) can be classified as either a light rare-earth element (LREE) or a heavy rare-earth element (HREE). The LREEs include the lanthanide elements from atomic number 57 (La) through atomic number 64 (Gd), and the HREEs include the lanthanide elements from atomic number 65 (Tb) through atomic number 71 (Lu). The division is based on the LREEs having unpaired electrons in the 4f electron shell and HREEs having paired electrons in the 4f electron shell.

Scandium (atomic number 21), a transition metal, is the lightest REE, but it is not classified as one of the group of LREEs nor one of the HREEs. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. Although its occurrence in crustal rocks is greater than that of lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.

Yttrium (atomic number 39), a transition metal, is chemically similar to the lanthanides and commonly occurs in the same minerals as a result of its similar ionic radius. Yttrium is included as an HREE even though it is not part of the lanthanide series.

The elemental forms of rare earths are iron-gray to silvery lustrous metals that are typically soft, malleable, ductile, and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798 °C for cerium to 1,663 °C for lutetium.

Legislation and Government Programs

In October, the U.S. Department of Defense, Defense Logistics Agency Strategic Materials (DLA Strategic Materials) announced the fiscal year 2017 (October 1, 2016, through September 30, 2017) Annual Materials Plan (AMP) for the National Defense Stockpile (NDS). The AMP included potential acquisitions of new NDS stocks. These included 18 t of europium (unspecified form), 10 t of yttrium oxide, and 0.5 t of dysprosium metal. At calendar yearend 2016, the NDS inventory included 8.8 t of yttrium oxide (Defense Logistics Agency Strategic Materials, 2016).

Under a Broad Agency Agreement (BAA) research contract with DLA Strategic Materials, Texas Mineral Resources Corp. (TMRC) (formerly Texas Rare Earth Resources Corp.) demonstrated the separation of REOs using proprietary continuous ion exchange and chromatography technologies. In a bench-scale demonstration for the BAA, TMRC produced compounds with purity greater than 99.996% from TMRC's Round Top deposit (Texas Mineral Resources Corp., 2016).

DLA Strategic Materials made six awards through a Small Business Innovation Research program aimed at demonstrating recovery or recycling of rare earths. Each award was approximately \$100,000, and the awards were primarily related to the permanent magnet industry. The awardees were Materials Modification Inc. (Fairfax, VA), Pioneer Astronautics (Lakewood, CO), TDA Research, Inc. (Wheat Ridge, CO), Urban Mining Co. (Austin, TX), XploSafe, LLC (Stillwater, OK), and Xylon Technical Ceramics Inc. (Alfred, NY) (U.S. Small Business Administration, 2018).

Researchers at the Critical Materials Institute (CMI), funded by the U.S. Department of Energy (DOE), were working to diversify supplies of critical materials, develop substitutes, improve rates of reuse and recycling, and study the cost and material supply chains of critical materials. CMI's projects covered a broad range of research areas, including recovering REEs from other commodity process streams, developing substitutes for REEs in magnets and phosphors, and improving manufacturing techniques and recycling (Critical Materials Institute, undated). In 2016, CMI reported its key technical successes, which included licensing a membrane-solvent extraction technology for REEs, making progress on a substitute for a europium-based red phosphor, and developing a new aluminum-cerium casting alloy (Critical Materials Institute, 2016, p. 3).

The DOE was funding research to find cost-effective methods to separate rare earths from coal and coal byproducts. After providing \$8 million for 10 projects in 2015, DOE's National Energy Technology Laboratory provided \$2 million in 2016 for 5 new projects from industry and academia to identify and characterize coal and coal byproducts containing high concentrations of REEs. Organizations receiving funding included Tetra Tech, Inc. (Pasadena, CA), University of Kentucky Research Foundation (Lexington, KY), West Virginia Water Research Institute (Morgantown, WV), and XLight Corp. (Morristown, NJ) (National Energy Technology Laboratory, 2015, 2016).

Production

Rare-earth mineral concentrates have not been produced in the United States since MolyCorp, Inc. (Greenwood Village, CO) placed its mining operations at Mountain Pass, CA, on care-and-maintenance status and filed for bankruptcy protection in 2015. In 2016, MolyCorp, exclusive of its subsidiary MolyCorp Minerals LLC (Mountain Pass, CA), emerged from bankruptcy protection as Neo Performance Materials Inc. (Toronto, Ontario, Canada). Neo Performance Materials retained ownership of nearly all of MolyCorp's global network of material processing operations in Asia, Europe, and the United States, including rare-earth mineral processing and separation plants in Sillamae, Estonia; Jiangyin, Jiangsu Province, China; and Zibo, Shandong Province, China. At yearend, the Mountain Pass operations remained idle (Neo Performance Materials Inc., 2016). Prior to MolyCorp's bankruptcy protection, Eutectix LLC (Troy, MI) acquired MolyCorp's metals and alloys operations at Tolleson, AZ (Eutectix LLC, 2016).

Rare-earth compounds and chemical intermediates were imported and processed into a variety of value-added products. Leading producers of rare-earth-bearing catalysts and chemical intermediates in the United States included Albemarle Corp. (Baton Rouge, LA), BASF Corp. (Florham Park, NJ), Solvay Chemicals, Inc. (Houston, TX), and W.R. Grace & Co. (Columbia, MD). Globe Metallurgical Inc. (Beverly, OH) and CC Metals and Alloys, LLC (Calvert City, KY) produced specialty ferroalloys containing REEs.

U.S. processors of rare-earth magnet alloys or rare-earth magnets included Arnold Magnetic Technologies Corp. (Rochester, NY), Electron Energy Corp. (Landisville, PA), Eutectix (Troy, MI, and Tolleson, AZ), and Hitachi Metals America, Ltd. (China Grove, NC).

In November, TdVib, LLC acquired ETREMA Products, Inc.'s assets in Ames, IA, where it produced the magneto-restrictive alloy Terfenol-D® containing dysprosium, iron (Fe), and terbium (TdVib, LLC, undated). A variety of scandium alloys and compounds were produced from imported materials in limited quantities. All domestic, commercially produced scandium and yttrium products were derived from imported compounds primarily sourced from China and Russia.

In 2016, publicly traded companies with plans to develop domestic resources of rare earths included Rare Element Resources Ltd. (RER) at its Bear Lodge project in Wyoming, NioCorp Developments Ltd. at its Elk Creek project in Nebraska, Texas Mineral Resources Corp. at its Round Top

project in Texas, and Ucore Rare Metals Inc. at its Bokan Mountain project in Alaska. Developers of domestic deposits that were considering scandium recovery in their project plans included NioCorp Developments Ltd., Texas Mineral Resources Corp., and Ucore Rare Metals Inc.

Owing to market conditions, RER postponed the development of the Bear Lodge deposit in Wyoming and suspended all permitting efforts. In 2017, RER planned to pursue offtake agreements, joint ventures, and the potential sale of various assets. Measured and indicated resources at Bear Lodge were 16.3 million metric tons (Mt) containing 3.07% (50,000 t) of REO equivalent using a 1.5%-REO cutoff (Rare Element Resources Ltd., 2017, p. 12, 36).

In 2016, Niocorp was working to advance permitting and pilot-plant trials in support of a feasibility study for the Elk Creek polymetallic project in Nebraska. At yearend, the company reported that it was completing feasibility studies and planned to provide scandium product samples to customers in 2017 (NioCorp Developments Ltd., 2016, p. 1; 2017, p. 15–16).

In Alaska, Ucore Rare Metals Inc. completed construction of a pilot plant based on molecular recognition technology (MRT) and began trial separations of feedstock from the Bokan-Dotson Ridge deposit. In November, Ucore announced plans to construct a domestic polymetallic production facility based on MRT and designed to process feedstocks containing REEs and platinum-group metals (Ucore Rare Metals Inc., 2017, p. 3).

Consumption

Owing to limited data transparency, industry estimates of global consumption of rare earths varied significantly and generally ranged from about 120,000 to 150,000 t (Adamas Intelligence, 2016, p. 105; Kingsnorth, 2016, p. 6; Roskill Information Services Ltd., 2016, p. 2). Global consumption was led, in descending order of quantity, by catalysts, magnets, polishing, and metallurgical applications. Other end uses included ceramics, glass, phosphors, pigments, and miscellaneous other uses.

Based on trade data and excluding stock changes, U.S. apparent consumption of rare earths was estimated to be 10,600 t of REO equivalent in 2016. The estimated domestic use of rare earths in 2016 was primarily in catalysts (55%), with the remainder in metallurgical applications and alloys (15%), polishing (10%), ceramics and glass (10%), and other uses (10%). The United States primarily consumed LREEs. Because the United States has limited capabilities to produce battery alloys, magnet alloys, and phosphors, most LREE consumption is in the form of cerium and lanthanum compounds used to produce catalysts, ceramics, glass, and polishing compounds. Most HREE consumption is in the form of yttrium compounds. Together, the remaining HREEs (Tb, Dy, Ho, Er, Tm, Yb, and Lu) were estimated to contribute less than 2% of domestic consumption.

The amount and specific REEs used varied significantly by market sector and application. In the catalysts sector, the primary REEs being consumed were lanthanum and cerium, with lesser amounts of neodymium. Consumption in the magnet sector varied by the type of permanent magnet. Neodymium-iron-boron magnets primarily used neodymium and praseodymium with lesser amounts of dysprosium, gadolinium,

and terbium; samarium-cobalt magnets used samarium and lesser amounts of gadolinium. Lanthanum was known to have limited use in certain ferrite magnets. Polishing compounds primarily used cerium with lesser amounts of lanthanum. Batteries primarily used lanthanum and lesser amounts of cerium as well as other REEs. Ceramics were dominated by yttrium consumption with lesser amounts of cerium and other REEs. Metallurgical applications varied by the application. For example, battery alloys primarily used lanthanum and lesser amounts of cerium and other REEs. Europium, yttrium, and terbium were the three REEs commonly associated with the phosphors sector, but other REEs were also used by that sector. The glass sector used lanthanum, cerium, and erbium, in descending order of consumption, as well as other REEs. The HREEs were often used in high-unit-value applications. For example, laser crystals were commonly based on neodymium and yttrium and were doped with the HREEs (particularly dysprosium, erbium, thulium, and ytterbium). Among its other uses, lutetium was used in positron emission tomography.

Global consumption of scandium was estimated to be 15 to 20 t. Although not quantified, the domestic end uses of scandium were primarily for fuel cells and as an additive in aluminum alloys; however, scandium for these applications was thought to be imported in the form of value-added intermediate products rather than imported under the Harmonized Tariff Schedule of the United States (HTS) codes for rare-earth metals (2805.30) and rare-earth compounds (2846). Globally, the leading end uses for scandium were aluminum-scandium alloys, fuel cells, and lasers.

Prices

Prices for most rare-earth products declined significantly compared with those in 2015 and continued downward trends that began after the price spikes in 2011. On a percentage basis, the largest declines in REO prices were led by europium (−78%) and yttrium (−50%). Prices for REOs were depressed by low capacity utilization and illegal production within China (SMM Information & Technology Co., Ltd., 2017). In the United States, according to information collected by the U.S. Census Bureau on imports, the unit values in many trade categories declined significantly with some exceptions that may have been caused by variations in the purity or mix of specific compounds being imported from year to year. Domestic prices for scandium materials quoted by a domestic supplier decreased by 10% compared with those in 2015.

Foreign Trade

Data in this section are reported in gross weight; data totals in the tables are also converted to REO equivalent content. The loss of domestic mine production caused a dramatic decrease in exports of rare-earth compounds. U.S. exports of all forms of rare-earth metals and compounds totaled 1,600 t of REO equivalent, a 74% decrease compared with those of 2015 (table 4).

Exports of rare-earth compounds were about 556 t of REO equivalent with China and the Netherlands as the leading export destinations. Exports of rare-earth metals under HTS code 2805.30, including unalloyed and alloyed metals but excluding ferrocium, increased by 71% compared with those of 2015.

The leading export destinations of rare-earth metals (excluding ferrocium) were China and India. Exports of ferrocium and other pyrophoric alloys under HTS code 3606.90 decreased by 23% compared with those of 2015 (table 4).

U.S. imports totaled 12,200 t of REO equivalent, a 23% increase compared with those of 2015 (table 5). About 94% of REO equivalent imports were in the compound form and 6% were metals. China continued to dominate most import HTS categories, and most of the rare-earth metals and compounds imported from other countries were ultimately derived from China's mineral feedstocks. Unalloyed cerium metal and compounds were estimated to be 16% of total REO equivalent imports. Imports of unalloyed lanthanum metal and compounds were estimated to be 41% of total REO equivalent imports. Scandium and yttrium compounds were estimated to be less than 1% of total REO equivalent imports.

World Review

Australia.—In the Northern Territory, Arafura Resources Ltd. continued to work on its Nolans Bore project with planned production of rare-earth, phosphate, and uranium products. In January, Arafura announced a Memorandum of Understanding with the Republic of Korea's OCI Co. Ltd. that included a joint venture to toll process mixed rare-earth intermediate compounds from Nolans Bore. In May, Arafura submitted an environmental impact study to the Northern Territory Environment Protection Authority and the Government of Australia's Department of the Environment and Energy. Measured resources at Nolan's Bore were 4.9 Mt containing 3.2% (158,000 t) REO and indicated resources were 30 Mt containing 2.7% (816,000 t) REO, using a 1%-REO cutoff grade. Arafura planned to produce 14,000 metric tons per year (t/yr) of REO equivalent (Arafura Resources Ltd., 2016, p. 3–5, 12).

Alkane Resources Ltd. continued to develop its polymetallic Dubbo Zirconia project in New South Wales with planned production of hafnium, niobium, rare-earth, tantalum, and zirconium products. In April, Alkane announced plans to toll process about 2,000 t/yr of REO equivalent using solvent extraction through Vietnam Rare Earth JSC. The project was expected to produce about 25,000 t/yr of various products, including about 6,660 t/yr of REO equivalent content. Reserves were 35.9 Mt of polymetallic ore containing 0.88% REO (including yttrium oxide), based on a 1.5% [combined niobium oxide, REO, and zirconium oxide (ZrO₂)] cutoff grade (Alkane Resources Ltd., 2016, p. 18–21).

In March, Clean TeQ Holdings Ltd. reported an increase in the resource estimate for its Syerston scandium project in New South Wales. Using a cutoff grade of 600 parts per million (ppm) scandium, the measured and indicated resources of the Syerston project were reported to be 1.4 Mt, containing about 2,200 t of scandium oxide equivalent (Clean TeQ Holdings Ltd., 2016, p. 5).

Feasibility studies were ongoing at Hastings Technology Metals Ltd.'s Yangibana project in Western Australia. In 2016, the company announced that measured resources were 2.16 Mt containing 1.01% REO equivalent and indicated resources were 5.45 Mt containing 1.3% REO equivalent (Hastings Technology Metals Ltd., 2017).

Lynas Corp. Ltd. continued to operate its Mt Weld mining operations in New South Wales to support its processing operations in Malaysia. The concentration plant at Mt Weld was designed to produce up to 66,000 t/yr of mineral concentrate (26,500 t/yr of REO equivalent) (Lynas Corp. Ltd., undated). As of June 30, proven and probable reserves were estimated to be 9.7 Mt containing 1.04 Mt of REO (Lynas Corp. Ltd., 2016, p. 90).

Metallica Minerals Ltd. continued to pursue the development of the polymetallic SCONI project in northern Queensland. In 2013, the measured and indicated resources of the SCONI project were reported to be about 10.8 Mt containing 1,790 t of scandium using a 100-ppm-Sc cutoff grade. The project's prefeasibility studies were based on an operation producing up to 50 t/yr of scandium oxide (Metallica Minerals Ltd., 2013, p. 10, 35). In 2016, Metallica announced that it had entered into a joint-venture agreement with Australian Mines Ltd., and a definitive feasibility study (DFS) was expected to be completed by 2020. Among the terms of the agreement was a payment of \$250,000 to Metallica. Australian Mines was expected to earn 50% interest in the project after the completion of a DFS or having expended \$10 million on the DFS within 4 years (Metallica Minerals Ltd., 2017, p. 10).

In 2016, Northern Minerals Ltd. pursued the development of mining and pilot-plant trials at the Browns Range project in Western Australia. The company expected the pilot plant to produce up to 590 t of REO equivalent in a mixed REO carbonate over a 3-year trial. At yearend, Northern Minerals' mining proposal was approved by the Western Australia Department of Mines and Petroleum. The company planned to begin mining 172,000 t of ore in 2017 to support the trial. Indicated resources for the Browns Range project were estimated to be 4.69 Mt containing about 0.7% (32,900 t) REO, using a cutoff grade of 0.15% REO. Probable reserves were 3.75 Mt containing about 0.7% (26,400 t) REO (Northern Minerals Ltd., 2015, p. 2; 2016).

Platina Resources Ltd. continued work on feasibility and environmental studies for its Owendale project in New South Wales. In July, Platina Resources announced mineral resource estimates for the project had increased. The revised indicated resource was 5.9 Mt containing 375 ppm scandium, using a cutoff of 300-ppm Sc. Measured resources were updated to 4.3 Mt containing 405 ppm scandium. The company planned to complete an environmental impact statement and a mining lease application in 2017 (Platina Resources Ltd., 2016a, p. 1; 2016b).

Scandium International Mining Corp. (Sparks, NV) completed a DFS and updated the mineral resource estimates for the Nyngan scandium project in New South Wales. Using a 100-ppm-Sc cutoff grade, measured and indicated resources were 16.9 Mt containing about 235 ppm scandium. Proven and probable reserves were estimated to be 1.44 Mt containing 409 ppm scandium. The DFS was based on a 20-year mine life and a production capacity of 38.5 t/yr with initial production scheduled to begin in 2018. In November, the company received an AUD629,000 research and development tax refund from the Government of Australia (Scandium International Mining Corp., 2016a, p. 1.5–1.6; 2016b).

Brazil.—Brazil exported an estimated 3,700 t of REE-bearing monazite concentrate to China in 2015 (Global Trade

Information Services Inc., 2018). Although no data were available for 2016, according to the Departamento Nacional de Produção Mineral (DNPM), Brazil's prior shipments were derived from Indústrias Nucleares do Brasil (INB) inventories in Sao Francisco do Itabapoana (Andrade, 2016, p. 108, 109). INB reported that it produced monazite concentrate from previously mined ore and mixed concentrates at its Buena operations in Sao Francisco de Itabapoana, Rio de Janeiro State (Indústrias Nucleares do Brasil S.A., undated).

Companhia Brasileira de Metalurgia e Mineração continued to pursue the commercial recovery of rare earths from monazite found in its Araxá mine tailings. The Araxá mining and processing operation in Minas Gerais State was a leading global source of niobium metal and compounds. In 2016, the company was reported to be capable of producing up to 3,000 t/yr of REO equivalent in compounds. Pilot-plant trials produced lanthanum, cerium, neodymium-praseodymium, and mixed HREE compounds (Senado Federal, 2013; Carneiro, 2015, p. 13; Villela, 2016).

Innovation Metals Corp. (Toronto, Ontario, Canada) announced that it had successfully demonstrated a proprietary solvent extraction process using feedstock from the Mineração Serra Verde deposit in Goiás State. The process reportedly reduced the number of separation stages, operating costs, and processing time compared with conventional processing. The demonstration produced commercially pure praseodymium-neodymium oxide and lanthanum oxide (Metal-Pages, 2016b).

Burundi.—At yearend, Rainbow Rare Earths Ltd. was preparing to file a prospectus on its Gakara project in Bujumbura Rural Province. The Gakara REE mineralization was described as a network of bastnäsite- and monazite-bearing veins and in situ grades in the range of 47% to 67% REO equivalent. According to the company prospectus, prior mining operations in the area produced about 2,500 t of REO equivalent from 1948 through 1978. Although the deposit was classified as an exploration target, the company was conducting trial bench mining in 2016 (Rainbow Rare Earths Ltd., 2017, p. 157–163).

Canada.—Owing to market conditions, Avalon Advanced Materials Inc.'s Nechalacho project at Thor Lake, Northwest Territories, was largely inactive. A National Instrument (NI) 43–101-compliant feasibility study filed in 2013 assumed a 20-year mine life with average production of 6,800 t/yr of separated REO and byproducts of tantalum, niobium, and zirconium oxides. The project's proven and probable mineral reserves were about 15 Mt containing 1.7% REO, using a cutoff grade based on value (Avalon Rare Metals Inc., 2013, p. 163–165; Avalon Advanced Materials Inc., 2017, p. 7–9).

Commerce Resources Corp. continued work on the development of its Ashram project in northern Quebec. In 2016, activities included a drilling program and the collection of environmental data. In June, the company announced that it was awarded CAD300,000 by Fonds de Recherche du Québec—Nature et Technologies and the Ministère de l'Énergie et des Ressources Naturelles to improve tailings management for the project. Measured and indicated resources were estimated to be 29.3 Mt containing 1.9% REO, using a 1.25%-REO cutoff grade. The project was based on a proposed production of 16,900 t/yr of REO primarily derived from monazite and to

a lesser degree bastnäsite and xenotime using conventional processing methods (Commerce Resources Corp., 2017, p. 2–4).

Matamec Explorations Inc. continued metallurgical testing as well as environmental and social impact studies at its Kipawa project in Quebec. Proven and probable mineral reserves were previously estimated to be 20 Mt containing 0.41% (82,000 t) REO using a cutoff value of \$48.96 per ton of ore. The dominant REE mineralization was reported to be the silicate minerals eudialyte and mosandrite (Matamec Explorations Inc., 2013, p. 12; 2017, p. 11; undated).

Medallion Resources Ltd. continued plans to develop a processing facility for the production of mixed rare-earth compounds from monazite. Medallion's proposed facility would purchase monazite byproduct from heavy-mineral-sands operations and produce rare-earth compounds. In 2016, the company was pursuing financing and partnerships to secure feedstocks of mineral concentrates (Medallion Resources Ltd., 2017, p. 1).

Search Minerals Inc. (North Vancouver, British Columbia) completed a preliminary economic analysis on its Foxtrot project in southeastern Labrador, Canada. According to the company, most of the rare-earth mineralization occurred in allanite (a silicate mineral) and fergusonite (an oxide mineral). The analysis was based on a combined open pit and underground mining approach followed by processing to produce a mixed rare-earth concentrate. Indicated resources were 7.4 Mt containing about 81,000 t of REO equivalent. Production of a mixed rare-earth compound was projected to average 3,300 t/yr of REO equivalent (Search Minerals Inc., 2016, p. 14–1).

China.—China dominated the global production of rare-earth minerals, separated compounds, and metals. Based on China's production quota, China accounted for more than 80% of global mine production in 2016. According to various industry analysts, about 20% to 40% of China's REO was produced illegally and production was well above the production quota (Adamas Intelligence, 2016, p. 47; Kingsnorth, 2016, p. 6; Roskill Information Services Ltd., 2016, p. 53). China's global share of production was nearly unchanged compared with that in 2015. Independent industry estimates of China's REO consumption were in the range of about 80,000 to 100,000 t (Adamas Intelligence, 2016, p. 135; Kingsnorth, 2016, p. 6; Roskill Information Services Ltd., 2016, p. 98).

China's Ministry of Land and Resources production quotas for rare-earth mine production were unchanged compared with 2015 at 105,000 t of REO equivalent, of which 87,100 t was for light rare earths and 17,900 t was for medium and heavy rare earths. The production quotas for smelting and separation were 99,550 t, 95% of the mine production quotas.

China continued to implement plans to integrate its rare-earth industry into six largely Province-based state-owned enterprises. The consolidated companies were Aluminum Corp. of China Ltd., Baotou Rare Earth Hi-Tech Holding Co. Ltd., China Minmetals Corp., Ganzhou Mining Group, Guangdong Rare Earth Group, and Xiamen Tungsten Group. Nearly all mine, smelting, and separation quotas were allocated to the state-owned enterprises (Asian Metal Inc., 2017).

In October, the Ministry of Industry and Information released a 5-year development plan for the rare-earth industry. The plan aimed to reduce REO separation capacity to 200,000 t by 2020 from 300,000 t in 2015. Actual production of separated REO was expected to be less than 140,000 t. The plan also targeted increased environmental compliance, reductions in exports, continued support for industry consolidation, and increased production of downstream materials (Ministry of Industry and Information Technology, 2016, p. 11).

China's imports of rare-earth compounds under the Harmonized System (HS) code 2846 were about 16,500 t (gross weight) in 2016 compared with 10,600 t in 2015. Increased imports from Burma, Malaysia, and Russia were primarily responsible for the significant increase. China's imports of rare-earth metals under HS code 2805.30 were 5 t, and nearly all imports were from Japan. Imports of thorium ores and concentrates (HS code 2612.20) containing REEs were 7,120 t (Global Trade Information Services Inc., 2018).

China's exports of rare-earth compounds (HS code 2846) were 42,100 t (gross weight) compared with 29,200 t in 2015. The top five destinations were, in descending order, the United States (34%), Japan (25%), the Netherlands (9%), Germany (8%), and the Republic of Korea (6%). China's exports of rare-earth metals under HS 2805.30 were 5,170 t, and Japan (67%) was the leading destination (Global Trade Information Services Inc., 2018).

Greenland.—Greenland Minerals and Energy Ltd. (GMEL) continued work on its polymetallic (REE-uranium-zinc) Kvanefjeld project in southern Greenland. In 2016, the Kvanefjeld environmental and social impact assessments were under review by the government of Greenland. In November, Shenghe Resources Holding Co. Ltd., a miner and processor of rare earths based in Chengdu, China, acquired a 12.5% interest in GMEL. The Kvanefjeld project's measured and indicated resources were reported to be 867 Mt containing about 1.14% (5.14 Mt) REO (Greenland Minerals and Energy Ltd., 2017, p. 6–14).

India.—On a gross-weight basis, India was a net importer of rare-earth compounds (546 t) and metals (450 t). According to India's Department of Atomic Energy in Mumbai, India's monazite resources in heavy-mineral sands were 11.9 Mt and included indicated, inferred, and speculative categories. India's producers of rare-earth-bearing heavy-mineral concentrates included Indian Rare Earths Ltd. (IREL) and Kerala Metals & Minerals Ltd. India's monazite production capacity was reported by the Indian Bureau of Mines to be 6,240 t/yr. In Odisha, IREL was commissioning a processing plant that consumed monazite and could produce up to 11,200 t/yr of mixed rare-earth chlorides. In June, the processing plant was reported to be operating at 25% of capacity (Metal-Pages, 2016a; Singh, 2016, p. 22; Global Trade Information Services Inc., 2018; Indian Bureau of Mines, 2018).

Saraf Titanium Industry planned to recover 2.5 t/yr of scandium oxide from the process streams of a titanium slag operation being constructed in Odisha. Scandium is contained in ilmenite mineral concentrates that were expected to be used as a feedstock for the titanium slag operation. The recovery of scandium was not expected for several years (Beijing Ruidow Information Technology Co. Ltd., 2016).

Japan.—Japan's Society of Newer Metals estimated the 2016 consumption of rare earths in Japan to be 16,800 t, a 9% increase compared with 15,400 t in 2015. Consumption included cerium (5,800 t), neodymium and praseodymium (4,000 t), mixed rare-earth metals (3,500 t), lanthanum (1,980 t), yttrium (820 t), other rare-earth compounds (613 t), samarium (80 t), and europium (13 t) (Japan Society of Newer Metals, 2017).

Kazakhstan.—Although no production was reported in 2016, Summit Atom Rare Earth Co. LLP (SARECO), a joint venture between Japan's Sumitomo Corp. (49%) and Kazakhstan's Kazatomprom National Atomic Co. (51%), planned to expand production capacity at its Stepnogorsk plant to 6,000 t/yr from 1,500 t/yr of REO equivalent in intermediate compounds. The plant was designed to recover rare earths from uranium-ore residue. In 2016, SARECO agreed to supply intermediate compounds to Irtysh Rare Earths Co. Ltd. for separation in Pervomaysky. REEtec AS (Oslo, Norway) conducted a trial using a proprietary separation technology on intermediate compounds supplied by SARECO (Kazatomprom National Atomic Co., 2017, p. 76).

Malaysia.—Lynas continued to increase production of rare-earth compounds at its Lynas Advanced Material Plant (LAMP) near the Port of Kuantan in the State of Pahang. Production of REO from the LAMP operations in 2016 was about 13,900 t, a 27% increase compared with production in 2015 (Lynas Corp. Ltd., 2016, p. 12; 2017, p. 17).

Philippines.—Japan's Sumitomo Metal Mining Co., Ltd. (SMM) announced plans to construct a commercial-scale plant to produce a scandium intermediate product at its subsidiary Taganito HPAL Nickel Corp. on Palawan Island. The plant was expected to recover up to 7.5 t/yr of scandium oxide equivalent from a process stream following the leaching of nickel laterite for nickel-cobalt sulfide. Processing of the intermediate product into scandium oxide was expected to be performed at SMM's Harima operation in Japan. SMM agreed to supply scandium oxide to a U.S. producer of fuel cells, and production was scheduled to begin in 2018 (Sumitomo Metal Mining Co., Ltd., 2016).

Russia.—Russian imports of rare-earth compounds (HS 2846) were about 873 t in 2016, and exports were 6,580 t. Rare-earth-metal (HS 2805.30) imports and exports were 75 t and 5 t, respectively. China was Russia's leading import source, and Estonia was the leading export destination (Global Trade Information Services Inc., 2018).

PJSC Acron commissioned a pilot plant to produce up to 200 t/yr of REO equivalent in the form of mixed and separated rare-earth compounds at its Veliky Novgorod facility. The feed for the operation was a byproduct apatite mineral concentrate sourced from the company's Oleniy Ruchey phosphate mine in the Murmansk Region. In 2016, Acron produced 62 t of REO equivalent (PJSC Acron, 2017, p. 44).

ARMZ Uranium Holding Co. was conducting pilot-plant studies at the JSC Dalur in situ uranium mining and processing operation in the Kurgan Region. ARMZ completed the design for a commercial plant to recover and produce up to 1.5 t/yr of scandium oxide equivalent. Commercial production was scheduled to begin in 2017 (JSC Atomredmetzoloto, 2017, p. 35, 37).

In 2016, JSC Solikamsk Magnesium Works (SMW) in Perm Krai reported consumption of about 8,760 t of loparite concentrates (containing 28% to 30% REO) sourced from the Lovozero GOK mining operations near Revda, in the Murmansk Region. Loparite concentrate consumption increased by 3% compared with that in 2015, continuing a positive trend that began in 2010. SMW's production increased to about 3,060 t of REO equivalent in 2016, a 32% increase compared with its production in 2015. SMW was reported to be capable of processing up to 13,000 t/yr of loparite concentrate and producing compounds with up to 3,600 t/yr of REO equivalent (JSC Solikamsk Magnesium Works, 2017, p. 5–12).

ThreeArc Mining LLC was working on exploration and development of the Tomtor deposit in the Olenyoksky District with planned production of niobium and rare-earth products. In 2016, ThreeArc completed a drilling program and conducted pilot-plant studies of chemical processing. Initial production was scheduled for 2021 and included 11,500 t/yr of REO equivalent. The company reported that 50 t/yr of scandium oxide equivalent was a potential byproduct for the project. In a separate project, ThreeArc signed an agreement with Rosatom State Nuclear Energy Corp. to process a state-owned stockpile of 82,000 t of monazite concentrate (Malach, 2016, p. 8–13; Metal-Pages, 2016d).

United Company RUSAL Plc, one of the world's leading aluminum producers, was conducting pilot-plant studies in the Ural Mountains to recover scandium concentrate from red mud. In 2016, Rusal's pilot plant was reported to have produced 10 kilograms of scandium oxide with 99.4% purity. At the company's Irkutsk aluminum smelter, plans for the commercial and pilot production of aluminum-scandium alloys and master alloys were underway (United Company RUSAL Plc, 2017, p. 54, 80).

South Africa.—Steenkampskraal Thorium Ltd. continued work on refurbishing the Steenkampskraal (SKK) monazite mine for the production of rare-earth minerals and thorium compounds for the production of thorium-based fuel for nuclear reactors (Biello, 2016). According to a NI 43–101-compliant study completed in 2013, using a 1%-REO cutoff grade, SKK's in situ measured resource was 85,000 t and contained about 19.5% (16,600 t) REO. Using the same cutoff basis, indicated resources were estimated to be 474,000 t and contained about 14.1% (67,000 t) REO (Great Western Minerals Group Ltd., 2014, p. 146, 147).

Sweden.—Tasman Metals Ltd., owner of the Norra Karr project in southern Sweden, was acquired by Flinders Resources Ltd, and the combined company was renamed Leading Edge Materials Corp. At yearend, the company was working to reinstate its exploration mining license for the project (Leading Edge Materials Corp., 2017). Probable reserves were previously reported to be about 23.6 Mt containing 0.592% (140,000 t) REO. Using a 0.4%-REO cutoff grade, indicated resources were 31.1 Mt containing 0.61% (190,000 t) REO. Nearly all of the REE mineralization was eudialyte. The prefeasibility study was based on a proposed production of about 5,000 t/yr of mixed REO and a 20-year mine life (Tasman Metals Ltd., 2015, p. 42–43).

Tanzania.—Peak Resources Ltd. was conducting pilot-plant studies for its Ngualla project in support of a bankable feasibility study scheduled to be completed in 2017. In December, Peak Resources selected a potential site in the United Kingdom to process mixed compounds from Tanzania. Proven and probable reserves for the project were reported to be 20.7 Mt containing 941,000 t of REO equivalent using a 3%-REO cutoff (Peak Resources Ltd., 2016, p. 11; 2017).

Vietnam.—Vietnam Rare Earth Co. Ltd. (VRE) was acquired by Shenghe Resources Singapore Pte Ltd. (90%) and a subsidiary of Chuo Denki Kogyo Co., Ltd. based in Japan (10%). VRE operated recycling, separation, metal, and magnet production operations in Thuan Thanh, Bac Ninh Province. In 2016, VRE was a toll processor of REE materials and had the capacity to produce more than 4,000 t/yr of separated REO compounds. The company's electrolytic metal capacity was 700 t/yr (Metal-Pages, 2016c).

Rare-earth reserves in Vietnam were reported to be 22 Mt with resources concentrated in Lai Chau (Nam Xe, Dong Pao) and Yen Bai (Yen Phu) Provinces and in mineral sands in the coastal Provinces from Thanh Hoa to Ba Ria-Vung Tau. Limited production of rare-earth minerals was reported from artisanal mining. According to news reports, thousands of tons of monazite concentrate from heavy-mineral sands were stored in warehouses (Vietnam National Coal Mineral Industries Holding Co. Ltd., 2016).

Outlook

Globally, the annual average growth rate of REE consumption is expected to exceed 5% through 2020. The magnet materials sector is expected to have higher average growth, and the catalysts and phosphors sectors are expected to have lower average growth. As the leading producer and consumer of rare-earth minerals and most downstream products, China is expected to continue to dominate the global markets for rare-earth compounds and metal alloys.

Beyond 2020, increased demand, industry consolidation in China, tighter enforcement of environmental compliance, and reductions in illegal mining are expected to result in higher prices for some REE materials. This scenario may accelerate the development of mining and processing projects outside of China.

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TABLE 1
SALIENT RARE-EARTH STATISTICS¹

		2012	2013	2014	2015	2016
United States:						
Production of rare-earth concentrates, rare-earth-oxide (REO) basis ^{e,2,3}	metric tons	3,000	5,500	5,400	5,900	--
Exports, REO basis: ^e						
Compounds:						
Cerium compounds	do.	996	734	608	440 ^r	309
Other rare-earth compounds	do.	1,830	5,570	3,780 ^r	4,540 ^r	247
Metals:						
Ferrocerium and pyrophoric alloys	do.	960	1,420	1,640	1,220	943
Rare-earth metals, scandium, yttrium	do.	2,080	1,050	140	60 ^r	103
Imports for consumption, REO basis: ^e						
Compounds:						
Cerium compounds	do.	1,390	1,110	2,990 ^r	1,440	1,830
Other rare-earth compounds	do.	3,400	7,330	9,260	7,720	9,650
Metals:						
Ferrocerium and pyrophoric alloys	do.	276	313	371	356	269
Rare-earth metals, scandium, yttrium	do.	240	393	348	385 ^r	404
World production, REO basis	do.	106,000	107,000	125,000	130,000	129,000
Prices, yearend:						
Monazite concentrate, REO basis ^e	dollars per kilogram	2.30	2.00	3.50	2.30 ^r	2.50
Mischmetal, 65% cerium, 35% lanthanum, metal basis ⁴	do.	14.00–16.00	9.00–10.00	9.00–10.00	5.20–6.00 ^r	4.65–5.60

^eEstimated. ^rRevised. do. Ditto. -- Zero.

¹Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits, except prices.

²Includes only the rare earths derived from bastnäsite.

³Sources: Molycorp, Inc., 2015a, Form 10-K—2014: Greenwood Village, CO, Molycorp, Inc., 148 p.; Molycorp, Inc., 2015b, Form 10-Q—For the quarterly period ending June 30, 2015: U.S. Securities and Exchange Commission, 71 p.

⁴Source: Argus Media group – Argus Metals International.

TABLE 2
RARE-EARTH CONTENTS OF SELECTED SOURCE MINERALS^{1,2}

(Percentage of total rare-earth oxide)

Primary source Bastnäsite	Country	Location	Rare-earth element symbol																	
			La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y			
	China	Bayan Obo, Nei Mongol Autonomous Region ³	23.00	50.00	6.20	18.50	0.80	0.20	0.70	0.10	0.10	0.10	0.10	0.10	NA	NA	NA	NA	NA	NA
Do.	do.	Dechang, Sichuan Province ⁴	35.63	43.81	4.73	13.06	1.22	0.23	0.52	0.06	0.09	0.05	0.04	0.01	0.06	NA	NA	NA	NA	0.40
Do.	do.	Maoniuping, Sichuan Province ⁴	29.49	47.56	4.42	15.18	1.24	0.23	0.65	0.12	0.21	0.05	0.06	0.04	0.05	0.01	0.01	0.01	0.70	0.70
Do.	do.	Weishan, Shandong Province ⁴	35.46	47.76	3.95	10.90	0.79	0.13	0.53	0.14	NA	NA	NA	NA	0.03	NA	NA	0.03	NA	0.76
Do.	United States	Mountain Pass, CA ⁵	34.00	48.80	4.20	11.70	0.79	0.13	0.21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.12
Loparite	Russia	Revda, Murmansk Oblast ⁶	25.00	50.50	5.00	15.00	0.70	0.09	0.60	NA	0.60	0.70	0.80	0.10	0.20	0.15	0.20	0.15	1.30	1.30
Monazite	Australia	Mount Weld Central Lanthanide, Western Australia ⁷	23.88	47.55	5.16	18.13	2.44	0.53	1.09	0.09	0.25	0.03	0.06	0.01	0.03	NA	NA	0.03	NA	0.76
Do.	China	Nangang, Guangdong Province ⁴	23.00	42.70	4.10	17.00	3.00	0.10	2.00	0.70	0.80	0.12	0.30	NA	2.40	0.14	0.14	2.40	2.40	2.40
Do.	India	Manavalakurichi, Tamil Nadu ⁸	22.00	46.00	5.50	20.00	2.50	0.02	1.20	0.06	0.18	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.45	0.45
Rare-earth laterite	China	Xunwu, Jiangxi Province ⁴	38.00	3.50	7.41	30.18	5.32	0.51	4.21	0.46	1.77	0.27	0.88	0.13	0.62	0.13	0.13	0.62	10.07	10.07
Do.	do.	Xinfeng, Jiangxi Province ⁴	27.26	3.23	5.62	17.55	4.54	0.93	5.96	0.68	3.71	0.74	2.48	0.27	1.13	0.21	0.21	1.13	24.26	24.26
Do.	do.	Longnan, Jiangxi Province ⁴	2.18	<1.09	1.08	3.47	2.34	<0.37	5.69	1.13	7.48	1.60	4.26	0.60	3.34	0.47	0.47	3.34	64.90	64.90
Xenotime	do.	Southeast Guangdong Province ⁹	1.20	3.00	0.60	3.50	2.20	0.20	5.00	1.20	9.10	2.60	5.60	1.30	6.00	1.80	1.80	6.00	59.30	59.30

Do., do. Ditto. NA Not available.

¹Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits; rows may not add to 100 percent.

²Rare earths are listed in order of atomic number except yttrium, which is listed after the last of the heavy-rare-earth lanthanide elements.

³Zang, Zhang Bao, Lu, Ke Yi, King, Kue Chu, Wei, Wei Cheng, and Wang. 1982, Rare-earth industry in China: Hydrometallurgy, v. 9, no. 2, p. 205–210.

⁴Yang, Xiaosheng, and Zhi Li, Ling. 2014, China's rare earth ore deposits and beneficiation techniques: ERES 2014—1st European Rare Earth Resources Conference, Milos, Greece, April 4–7, 11 p.

⁵Molycorp, Inc., 2015, Form 10-K—2014: Greenwood Village, CO, Molycorp, Inc., 145 p. (Accessed June 30, 2016, at <http://www.molycorp.com/investors>.)

⁶Hedrick, J.B., Sinha, S.P., and Kosynkin, V.D., 1997, Loparite, a rare-earth ore: Journal of Alloys and Compounds, v. 250, p. 467–470.

⁷Lynas Corp. Ltd., 2012, Increase in Mt Weld resource estimate for the Central Lanthanide deposit and Duncan deposit: Sydney, New South Wales, Australia, Lynas Corp. Ltd. news release, January 18, 5 p.

⁸Patra, R.N., 2014, Latest scenario in rare earth and atomic minerals in India: PDAC Convention 2014, Toronto, Ontario, Canada, March 2–4, 42 p.

⁹Nakamura, Shigeo, 1988, China and rare metals—Rare earth: Industrial Rare Metals, no. 94, May, p. 23–28.

TABLE 3
RARE-EARTH-OXIDE PRICES¹

(Dollars per kilogram)

Product (oxide)	Purity	2015	2016
	(percent)		
Scandium ²	99.990	5,100	4,600
Yttrium ³	99.999	8	4
Lanthanum ³	99.500 ^r	3	2
Cerium ³	99.500 ^r	3	2
Praseodymium ³	99.500 ^r	76 ^r	52
Neodymium ³	99.500 ^r	48	40
Samarium ³	99.500 ^r	3	2
Europium ³	99.990 ^r	344 ^r	74
Gadolinium ³	99.999 ^r	21 ^r	20
Terbium ³	99.990	564 ^r	415
Dysprosium ³	99.500 ^r	279 ^r	195

^rRevised.

¹Table includes data available through August 17, 2018.

Products are listed in order of atomic number.

²Source: Stanford Metals Corp.

³Source: Argus Media group – Argus Metals International.

TABLE 4
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY OR LOCALITY¹

Category ² and country or locality	2015		2016	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Compounds:				
Cerium compounds (2846.10.0000):				
Austria	19,900	\$295,000	18,400	\$244,000
China	70,400	1,120,000	17,300	563,000
Egypt	76,800	793,000	--	--
Germany	109,000	1,180,000	28,800	682,000
Hong Kong	11,500	875,000	12,600	440,000
Japan	40,600	592,000	33,800	445,000
Korea, Republic of	31,000	756,000	6,550	158,000
Netherlands	6,680	58,700	211,000	305,000
Singapore	186,000	2,760,000	1,780	114,000
South Africa	10,700	42,500	6,910	27,700
Taiwan	18,500	355,000	67,400	370,000
United Kingdom	17,100	350,000	13,200	224,000
Other	59,700 ^r	1,550,000 ^r	43,500	1,270,000
Total	658,000	10,700,000	461,000	4,840,000
Total estimated rare-earth-oxide (REO) equivalent	440,000	XX	309,000	XX
Scandium or yttrium oxides (2846.90.2015):				
China	34,100	58,800	--	--
Germany	1,440	276,000	1,160	334,000
Other	3,130	254,000	897	119,000
Total	38,700	588,000	2,060	453,000
Total estimated REO equivalent	38,700	XX	2,060	XX

See footnotes at end of table.

TABLE 4—Continued
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY OR LOCALITY¹

Category ² and country or locality	2015		2016	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Compounds:—Continued				
Other rare-earth compounds ³ (2846.90.2040, 2846.90.2060, 2846.90.9000):				
China	2,990,000	\$9,140,000	67,100	\$975,000
Estonia	200,000	197,000	--	--
Germany	3,830,000 [†]	7,570,000 [†]	21,600	441,000
Mexico	167,000	1,410,000	32,200	2,720,000
Thailand	145,000	6,770,000	50,800	1,540,000
Vietnam	170,000	7,540,000	1,670	47,800
Other	481,000 [†]	11,200,000 [†]	271,000	6,110,000
Total	7,990,000	43,800,000	445,000	11,800,000
Total estimated REO equivalent	4,500,000	XX	245,000	XX
Metals:				
Ferrocerium and other pyrophoric alloys (3606.90.0000):				
Australia	20,800	5,020,000	22,100	296,000
Barbados	54,000	113,000	46,700	126,000
Canada	345,000	1,250,000	326,000	1,110,000
China	12,600	444,000	33,100	983,000
Colombia	37,200	95,800	3,820	9,340
Costa Rica	178,000	260,000	11,200	74,400
Dominican Republic	227,000	334,000	194,000	277,000
Hong Kong	48,900	1,690,000	1,080	39,800
Jamaica	61,400	107,000	48,300	307,000
Japan	19,100	780,000	16,200	605,000
Mexico	70,400	708,000	72,900	632,000
Panama	25,800	60,200	56,100	84,900
Trinidad and Tobago	42,900	80,600	48,000	65,800
United Kingdom	124,000	1,560,000	73,600	908,000
Other	106,000 [†]	3,310,000 [†]	109,000	2,750,000
Total	1,370,000	15,800,000	1,060,000	8,270,000
Total estimated REO equivalent	1,220,000	XX	943,000	XX
Rare-earth metals and alloys (2805.30.0000):				
Australia	6,870	60,100	6,810	47,700
Brazil	2,080	14,900	1,090	5,870
Canada	1,940	103,000	1,910	72,100
China	4,880	279,000	38,900	790,000
Germany	1,570	152,000	3,700	141,000
Hungary	1,140	98,200	1,510	135,000
India	5,220	229,000	12,000	517,000
Japan	2,120	125,000	1,570	128,000
Mexico	2,410	263,000	3,860	308,000
Netherlands	3,520	61,700	209	25,600
Spain	7,430	57,600	--	--
United Kingdom	2,140	125,000	5,030	252,000
Other	6,040 [†]	2,180,000 [†]	4,390	693,000
Total	47,300	3,750,000	81,000	3,120,000
Total estimated REO equivalent	60,100 [†]	XX	103,000	XX

[†]Revised. XX Not applicable. -- Zero.

¹Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States code.

³Inorganic and organic.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY OR LOCALITY¹

Category ² and country or locality	2015		2016	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Compounds:				
Cerium oxides (2846.10.0010):				
China	402,000	\$1,770,000	801,000	\$1,770,000
Japan	292,000	13,500,000	332,000	13,100,000
Other	35,000	656,000	18,700	723,000
Total	730,000	15,900,000	1,150,000	15,600,000
Total estimated rare-earth-oxide (REO) equivalent	730,000	XX	1,150,000	XX
Cerium compounds, other than cerium oxide (2846.10.0050):				
China	302,000	1,490,000	424,000	3,600,000
Estonia	658,000	2,080,000	525,000	888,000
Other	105,000 ^r	4,850,000 ^r	68,800	1,540,000
Total	1,060,000 ^r	8,420,000 ^r	1,020,000	6,030,000
Total estimated REO equivalent	712,000 ^r	XX	681,000	XX
Other rare-earth compounds:				
Carbonates:				
Lanthanum carbonates mixtures (2846.90.8070):				
China	755,000	2,220,000	2,330,000	4,290,000
Other	212 ^r	26,700 ^r	14	38,000
Total	755,000 ^r	2,250,000 ^r	2,330,000	4,330,000
Total estimated REO equivalent	517,000 ^r	XX	1,600,000	XX
Other rare-earth carbonates mixtures (2846.90.8075):				
China	2,400	127,000	3,450	172,000
Estonia	38,000	123,000	--	--
Other	165 ^r	40,800 ^r	4	21,400
Total	40,600	290,000	3,450	193,000
Total estimated REO equivalent	22,300	XX	1,900	XX
Chlorides:				
Scandium or yttrium chloride mixtures (2846.90.2082):				
Korea, Republic of	37	9,100	109	26,000
Other	15 ^r	13,300 ^r	1	5,260
Total	52	22,400	110	31,300
Total estimated REO equivalent	19	XX	41	XX
Unspecified mixtures of oxides or chlorides (2846.90.2084):				
China	222,000	1,130,000	345,000	946,000
Estonia	20,000	947,000	80,000	140,000
France	37,400	1,320,000	37,100	1,170,000
Other	40,900 ^r	136,000 ^r	4,220	192,000
Total	320,000	3,530,000	466,000	2,450,000
Total estimated REO equivalent	176,000	XX	256,000	XX
Oxides:				
Lanthanum oxides (2846.90.2005):				
China	2,960,000 ^r	10,700,000 ^r	3,320,000	7,370,000
Other	36,600 ^r	723,000 ^r	11,300	56,200
Total	3,000,000 ^r	11,400,000 ^r	3,330,000	7,430,000
Total estimated REO equivalent	3,000,000	XX	3,330,000	XX
Scandium or yttrium oxides (2846.90.2015):				
China	5,560	102,000	4,000	221,000
Estonia	20,000	109,000	--	--
France	4,880	512,000	--	--
Korea, Republic of	731	190,000	3,660	333,000
Other	130 ^r	24,400 ^r	1,690	105,000
Total	31,300	937,000	9,340	659,000
Total estimated REO equivalent	31,300	XX	9,340	XX

See footnotes at end of table.

TABLE 5—Continued
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY OR LOCALITY¹

Category ² and country or locality	2015		2016	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Compounds:—Continued				
Other rare-earth compounds:—Continued				
Oxides:—Continued				
REOs except cerium oxide (2846.90.2040):				
China	66,900	\$3,020,000	70,700	\$2,860,000
Germany	16,800	2,990,000	2,200	270,000
Japan	4,970	342,000	282	66,600
Other	6,680 ^r	287,000 ^r	6,510	228,000
Total	95,400	6,650,000	79,700	3,420,000
Total estimated REO equivalent	95,400	XX	79,700	XX
Other rare-earth compounds or mixtures:				
Unspecified compounds or mixtures (2846.90.8090):				
China	4,670,000	54,800,000 ^r	6,010,000	31,800,000
Estonia	297,000 ^r	1,870,000 ^r	341,000	717,000
France	381,000	7,730,000	644,000	14,500,000
Malaysia	800,000	2,740,000	440,000	820,000
Other	823,000 ^r	25,200,000 ^r	401,000	17,100,000
Total	6,970,000	92,300,000 ^r	7,830,000	64,900,000
Total estimated REO equivalent	3,830,000	XX	4,310,000	XX
Yttrium materials and compounds content by weight greater than 19% but less than 85% oxide equivalent (2846.90.4000):				
China	75,600	6,160,000	114,000	2,900,000
Other	8,420 ^r	5,260,000 ^r	4,140	1,720,000
Total	84,000	11,400,000	118,000	4,620,000
Total estimated REO equivalent	50,400	XX	71,000	XX
Metals:				
Ferrocerium and other pyrophoric alloys (3606.90.3000):				
Austria	39,100	444,000 ^r	51,800	525,000
China	206,000	2,560,000	145,000	1,900,000
France	139,000	3,080,000	27,900	609,000
Spain	6,730	139,000	55,300	1,170,000
Other	9,790 ^r	87,000 ^r	21,400	163,000
Total	401,000	6,310,000	302,000	4,360,000
Total estimated REO equivalent	356,000	XX	268,000	XX
Rare-earth metals and alloys:				
Cerium, unalloyed (2805.30.0010):				
China	97,300	841,000	64,700	370,000
Hong Kong	18,500	129,000	20,000	78,600
Other	1,180	73,500	301	17,800
Total	117,000	1,040,000	85,000	467,000
Total estimated REO equivalent	144,000 ^r	XX	104,000	XX
Lanthanum, unalloyed (2805.30.0005):				
China	61,900	464,000	43,100	361,000
Other	--	--	352	35,000
Total	61,900	464,000	43,400	396,000
Total estimated REO equivalent	72,600	XX	50,900	XX
Neodymium, unalloyed (2805.30.0020):				
China	1,940	223,000	4,060	147,000
Japan	417	12,400	601	97,400
Thailand	1,500	69,000	--	--
United Kingdom	680	105,000	2,000	60,800
Other	200 ^r	8,000 ^r	500	21,000
Total	4,730	417,000	7,170	327,000
Total estimated REO equivalent	5,520 ^r	XX	8,360	XX

See footnotes at end of table.

TABLE 5—Continued
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY OR LOCALITY¹

Category ² and country or locality	2015		2016	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Metals:—Continued				
Rare-earth metals and alloys:—Continued				
Other rare-earth metals, unalloyed (2805.30.0050):				
China	59,200	\$857,000	37,500	\$865,000
Other	2,250	192,000	5,950	490,000
Total	61,400	1,050,000	43,400	1,360,000
Total estimated REO equivalent	73,700	XX	52,100	XX
Other rare-earth metals, alloys (2805.30.0090):				
China	46,200	378,000	139,000	673,000
Japan	18,800	519,000	14,100	327,000
Other	9,250 ^r	479,000 ^r	3,560	313,000
Total	74,300	1,380,000	157,000	1,310,000
Total estimated REO equivalent	89,100	XX	188,000	XX

^rRevised. XX Not applicable. -- Zero.

¹Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States code.

Source: U.S. Census Bureau.

TABLE 6
RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY¹

(Metric tons, rare-earth oxide equivalent)

Country or locality ²	2012	2013	2014	2015	2016
Australia	3,220 ^r	3,000 ^e	8,000 ^e	12,000 ^e	15,000 ^e
Brazil ^c	1,620	330	--	880	2,200
China ^{e,3}	93,800	93,800	105,000	105,000	105,000
India ^{e,4}	1,700	1,700	1,700	1,700	1,500
Malaysia ^e	100	180	240	310	300
Russia ^e	2,200	2,500	2,600	2,800	2,800
Thailand ^{e,5}	120	130	1,900	760	1,600
United States ^e	3,000	5,500	5,400	5,900	--
Vietnam ^{e,5}	200	100	--	250	220
Total	106,000	107,000	125,000	130,000	129,000

^eEstimated. ^rRevised. -- Zero.

¹Table includes data available through November 9, 2017. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²In addition to the countries and (or) localities listed, rare-earth minerals were thought to have been produced in Indonesia, Nigeria, North Korea, and some Commonwealth of Independent States countries, but information was inadequate to make reliable estimates of output.

³Official production quota. Illegal production could not be quantified.

⁴India's Department of Atomic Energy did not report monazite production data.

⁵Rare-earth-oxide content of exports.