2019 Minerals Yearbook

RARE EARTHS [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

June 2024

Rare Earths

By Joseph Gambogi

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

In 2019, world rare-earth mine production was 219,000 metric tons (t) of rare-earth-oxide (REO) equivalent (tables 1, 8). China continued to dominate global production and consumption of rare-earth mineral concentrates, compounds, and metals (table 8). Rare earths were used in a variety of applications important to the economy, such as alloys, batteries, catalysts, ceramics, glass, magnets, phosphors, and polishing compounds. Domestic and global reserves of REO were 1.4 and 120 million metric tons (Mt), respectively. In North America, measured and indicated resources of rare earths were estimated to include 2.7 Mt of REO equivalent in the United States and more than 15 Mt in Canada.

Primary mining operations in Mountain Pass, CA, combined with byproduct production in Offerman, GA, produced a total of 28,000 t of REO equivalent in mineral concentrates in 2019. The value of U.S. exports of rare-earth materials included compounds ($83.1 million), ferrocerium ($11.5 million), and metals ($1.62 million) (tables 4, 5). The value of U.S. imports including compounds, ferrocerium, metal, and mineral concentrates totaled about $159 million (tables 6, 7). Prices for rare-earth oxides varied in 2019. Europium, neodymium, praseodymium, and scandium all decreased significantly. Cerium, lanthanum, samarium, and yttrium were relatively unchanged compared with prices in 2018. Prices for dysprosium, gadolinium, and terbium oxides increased (table 3).

The rare earths are a group of moderately abundant elements consisting of 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 bastnaesite, loparite, monazite, xenotime, and the lateritic ion-adsorption clays. The percentage distribution of REOs in mineral concentrates varies 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 either an LREE or an HREE. 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. Because of its common sources and chemical similarities, 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 degrees Celsius (°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 announced the fiscal year 2020 (October 1, 2019, through September 30, 2020) Annual Materials Plan (AMP) for the National Defense Stockpile (NDS). The AMP includes potential acquisitions of new NDS stocks. In fiscal year 2019, these potential acquisitions included 900 t of cerium (unspecified form), 4,100 t of lanthanum (unspecified form), and 100 t of rare-earth magnet feedstock (Defense Logistics Agency Strategic Materials, 2019).

In fiscal year 2019, under the Small Business and Innovative Research (SBIR) program, the Defense Logistics Agency supported research for the recovery of rare earths from end-of-life magnets. A $100,000 award was granted to Advanced Cooling Technologies, Inc. to develop technology that would use grinding magnets combined with mild acid leaching. The process would avoid the use of strong acids which cause environmental challenges (U.S. Small Business Administration, 2021).

In 2019, the U.S. Department of Energy (DOE) made four awards under an SBIR program related to the extraction and recovery of rare earths from coal ash and other unconventional sources. The Phase 1 award recipients and respective topic areas included Faraday Technology, Inc. (Englewood, OH), $206,500, low-temperature reduction of rare-earth metals using ionic liquids; Triton Systems, Inc. (Chelmsford, MA), $206,134, rare-earth-element harvesting from seawater brine using reverse osmosis; Technology Holding, LLC (Salt Lake City, UT), $200,000, nanoporous atomically thin membranes for desalination and rare-earth materials recovery; and Materials Research LLC (Palo Alto, CA), $199,927, silicon-calcium based reduction of rare-earth oxides (U.S. Small Business Administration, 2021).

The DOE continued to fund research in pursuit of methods to separate rare earths from coal and coal byproducts (including effluents). In fiscal year 2019, the DOE contributed $7 million toward an $8.8 million research collaboration led by the University of Kentucky (UK) focused on extraction of REEs from coal byproducts. The UK operated a pilot-scale plant for the extraction of REEs from Central Appalachian and Illinois Basin bituminous coal preparation plant refuse materials and produced a concentrate of up to 98% oxide equivalent. The DOE contributed $3.4 million toward a $4.3 million research collaboration led by the University of West Virginia (WVU) focused on developing innovative rare-earth extraction from acid coal mine drainage. The WVU operated a bench-scale facility using 500 to 1,000 grams per hour of solid residues generated from acid mine drainage and successfully produced a 93% REO concentrate (National Energy Technology Laboratory, 2019, p. 78–83). Researchers at the Critical Materials Institute (CMI), funded by the DOE, continued their efforts to diversify supply, develop substitutes, and improve reuse and recycling of rare earths. In fiscal year 2019, the funding for the CMI was $25 million from the DOE and a $1 million cost share from its collaborators (U.S. Department of Energy, 2019, p. 3).

In July 2019, five Presidential determinations were published concerning the domestic production of REEs. Domestic production capability for REE compounds, metals and alloys, and magnets were determined to be essential to the national defense. The determinations enabled the U.S. Department of Defense to use of Defense Production Act title III authorities to strengthen the domestic industrial base and supply chain for REEs (U.S. Department of Defense Industrial Policy, 2020, p.76).

Rare Resource Recycling Inc. (Houston, TX) was in the second phase of an SBIR project supported by the National Science Foundation to recycle REEs from neodymium magnets. The first phase of the project successfully demonstrated the feasibility of developing a process beyond laboratory scale to pilot scale. The second phase of the project was expected to result in a pilot-scale production plant with product yields greater than 95% and purity greater than 99%. The first and second phase project awards totaled $900,000 (National Science Foundation, 2019).

Production

The U.S. Geological Survey developed domestic mine production data for rare-earth minerals from a voluntary canvass of U.S. mining operations and information gathered from publicly available reports. In 2019, rare-earth mineral concentrates were produced domestically by MP Mine Operations LLC, doing business as MP Materials, and The Chemours Co., through its acquisition in August of Southern Ionics Minerals LLC. Bastnaesite mineral concentrates were produced as a primary product by MP Materials at mining and processing operations in Mountain Pass, CA. The Mountain Pass operations produced mineral concentrates in 2019; however, the downstream cracking and solvent extraction production capacity at Mountain Pass were idle. Monazite concentrates were recovered as a byproduct of processing heavy-mineral sands from operations near Offerman, GA.

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). CC Metals and Alloys, LLC (Calvert City, KY) and Globe Metallurgical Inc. (Beverly, OH) produced specialty ferroalloys containing REEs. U.S. producers of rare-earth alloys or magnets included Electron Energy Corp. (Landisville, PA); Eutectix LLC (Troy, MI, and Tolleson, AZ); and TdVib, LLC (Boone, IA). Urban Mining Co. (Austin, TX) was preparing to construct a commercial operation to recycle and produce rare-earth magnets in San Marcos, TX. Rare Earth Salts (Beatrice, NE) was working to commercialize a proprietary process to produce separated rare-earth compounds.

A variety of specialty alloys and compounds containing rare earths were produced from imported materials.

In addition to MP Materials and Chemours, companies with plans to develop domestic mine production of rare earths included NioCorp Developments Ltd. at its Elk Creek project in Nebraska; Rare Element Resources Ltd. at its Bear Lodge project in Wyoming; Texas Mineral Resources Corp. (TMRC) at its Round Top project in Texas; and Ucore Rare Metals Inc. at its Bokan Mountain project in Alaska. In addition to the lanthanides and yttrium, several companies were considering scandium recovery in their project plans.

Australia-based Lynas Corp. Ltd. and Blue Line Corp. signed a memorandum of understanding to develop REE separation capacity in the United States. The two companies planned to construct an REE separation facility at Blue Line's operations in Hondo, TX. Initially, the joint venture was expected to focus on HREE separations, but the venture could potentially produce LREEs (Lynas Corp. Ltd., 2019, p. 23; 2020a).

Following the completion of a revised National Instrument 43–101-compliant feasibility study for its Elk Creek polymetallic (niobium-titanium-scandium) project in Nebraska, NioCorp was pursuing engineering studies and environmental permitting efforts. According to the company, the indicated resource was 90.9 Mt of ore containing 70 grams per metric ton (6,300 t) of elemental scandium using a cutoff based on a $180 per ton net smelter return (NSR). The NSR was based on revenue from niobium, titanium, and scandium oxides (NioCorp Developments Ltd., 2017, p. 443; 2020, p. 15).

Rare Element Resources entered into an agreement with Umwelt-und Ingenieurtechnik GmbH Dresden (UIT) to conduct pilot-scale testing of its hydrometallurgical recovery and separation technology. UIT, an affiliate of General Atomics Technologies Corp. and Synchron, was expected to expand on its pilot-plant studies in 2020. Measured and indicated resources at Rare Element Resources' Bear Lodge project were 16.3 Mt containing 3.07% (500,000 t) of REO equivalent using a 1.5%-REO cutoff (Rare Element Resources Ltd., 2018, p. 37; 2020, p. 56–57).

TMRC was partnering with USA Rare Earth, LLC to advance its polymetallic Round Top project. In an agreement between the two companies, USA Rare Earth would assist in the development of the project through to bankable feasibility and could be entitled to up to a 70% interest in the project. Measured and indicated resources for the Round Top project were previously reported to be 480 Mt containing about 300,000 t of REO equivalent. At yearend, TMRC was in the process of commissioning a pilot plant in Wheat Ridge, CO, using continuous ion exchange–continuous ion chromatography separation technology (Texas Mineral Resources Corp., 2014, p. 13; 2020, p. 13–15).

Ucore was proceeding with plans to develop a processing and separation facility to produce rare earths and other metals in Alaska. In 2019, the company's strategic plan included potentially using a mix of solvent extraction and new technology to process and separate REEs. In December, the company announced that it was partnering with Materion Corp. and others with the objective of developing domestic production of HREEs, potentially with support from the U.S. Department of Defense. Ucore's strategic plan also included plans to develop the Bokan-Dotson deposit. In December, Ucore updated its resource estimate for the project to include beryllium, hafnium, niobium, titanium, vanadium, and zirconium. Using a 0.4%-REO cutoff, the Bokan Project's indicated resources were estimated to be 4.8 Mt containing about 32,000 t of REO equivalent (Ucore Rare Metals, Inc., 2020, p. 6, 22).

Consumption

Owing to limited data transparency, industry estimates of global consumption of rare earths varied significantly. Based on global mine production, consumption was estimated to be about 150,000 t. Global consumption was led, in descending order of quantity, by magnets, catalysts, 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 of compounds and metals was estimated to be about 12,000 t of REO equivalent in 2019.

The estimated domestic use of rare earths in 2019 was primarily in catalysts (75%), with the remainder, in descending order, in ceramics and glass, metallurgical applications and alloys, polishing, and other uses.

The United States primarily consumed LREEs. Because the United States had limited capabilities to produce battery alloys, magnet alloys, and phosphors, most LREE consumption was in the form of cerium and lanthanum compounds used to produce catalysts, ceramics, glass, and polishing compounds; ferrocerium and rare-earth metals were used for alloys and other metallurgical applications. Most HREE consumption was 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% to domestic consumption.

The amount of specific REEs used varied significantly by market sector and application. In the catalysts sector, the primary REEs 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 had 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 element. Europium, yttrium, and terbium were the three REEs commonly associated with the phosphors sector, but other REEs also were 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 25 metric tons per year (t/yr). 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 rare-earth products are influenced by the overall production of REO and the demand for specific elements in a wide variety of end uses. In 2019, REO prices for cerium and lanthanum primarily used in catalyst applications were relatively unchanged compared with those in 2018. In magnet end uses, prices for neodymium and praseodymium oxides decreased by 10% and 14%; samarium prices were unchanged; and dysprosium and terbium oxides prices increased by 34% and 11%, respectively. In phosphor end uses, europium oxide prices decreased by 34%. Prices for yttrium oxide used in ceramics and a variety of other end uses were unchanged. The domestic price for scandium oxide quoted by a domestic supplier decreased by 15% compared with that in 2018 (table 3).

Based on information collected by the U.S. Census Bureau on imports, the estimated unit value of REO in rare-earth compounds was about $12 per kilogram compared with $14 per kilogram in 2018. Variations in the purity or mix of specific compounds imported from year to year affect the unit value of imports (table 6).

Foreign Trade

Owing primarily to the resumption of production and export of rare-earth mineral concentrates from Mountain Pass, total exports of rare-earth compounds and metals increased substantially to 29,500 t of REO equivalent, a 54% increase compared with those in 2018. Exports of rare-earth compounds that included bastnaesite mineral concentrates were about 27,300 t of REO equivalent. Exports of rare-earth metals under HTS code 2805.30, including unalloyed and alloyed metals but excluding ferrocerium, were 83 t, an increase compared with 28 t in 2018. The leading export destinations of rare-earth metals (excluding ferrocerium) were Brazil, China, and the United Kingdom. Exports of ferrocerium and other pyrophoric alloys under HTS code 3606.90 were 1,450 t, a slight increase compared with those in 2018 (tables 1, 4, 5).

U.S. imports totaled 13,300 t of REO equivalent, a 14% increase compared with those in 2018. About 93% of REO-equivalent imports were in the compound form and 7% were metals (tables 1, 6, 7). China continued to dominate most HTS import categories and most of the rare-earth metals and compounds imported from other countries likely had been derived from China's mineral feedstocks or intermediate compounds. Cerium compounds and lanthanum compounds were the leading categories for specific rare earths, but most imports were in unspecified HTS categories.

Imports of rare-earth metals under HTS code 2805.30, including unalloyed and alloyed metals but excluding ferrocerium, were 519 t on a gross weight basis, whereas imports of ferrocerium and pyrophoric alloys under HTS code 3606.90.30 were 374 t. Imports of unalloyed REE metals were 427 t and were primarily cerium or lanthanum. Imports of other rare-earth alloys were 91 t on a gross weight basis (table 7).

World Review

Australia.—Geoscience Australia's national assessment of reserves compliant with the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves Joint Ore Reserve Committee (JORC) were about 3.0 Mt of REO. Geoscience Australia's classification for economic demonstrated resources (EDR) were 4.03 Mt of REO equivalent at the end of December 2019. Australia's EDR included reserves and measured and indicated resources but excluded about 27 Mt of inferred resources. The EDR for scandium was assessed separately and determined to be 27,000 t. JORC-compliant reserves for scandium were about 13,000 t (Geoscience Australia, 2021, p. 6, 10).

Australia was an active geographic region for mineral exploration and development. Publicly listed companies developing projects with JORC-compliant rare-earth reserves in Australia included Alkane Resources Ltd. (Dubbo Zirconia), Arafura Resources Ltd. (Nolans Bore), Australian Mines Ltd. (Sconi), Clean TeQ Holdings Ltd. (Sunrise), Hastings Technology Metals Ltd. (Yangibana), Lynas (Mount Weld), Northern Minerals Ltd. (Browns Range), Platina Resources Ltd. (Owendale), and Scandium International Mining Corp. (Nyngan).

Heavy-mineral sands producer, Iluka Resources Ltd., was proceeding with its Eneabba Mineral Sands Recovery Project. Iluka planned to process a stockpile of historical tailings to produce byproducts including REEs, titanium, and zirconium mineral concentrates. The measured and indicated resources of the stockpile were estimated to be about 1 Mt grading 83% heavy minerals. Monazite and xenotime constituted about 20% and 1.2%, respectively, of the heavy minerals fraction (Iluka Resources Ltd., 2019, p. 2).

Lynas, a leading producer of rare-earth mineral concentrates outside of China in 2019, continued to operate its Mount Weld mining operations in Western Australia to support its processing operations in Malaysia. In 2019, Lynas announced plans to expand and improve its mining and processing operations by 2025 with a production target of 10,500 t/yr of Nd-Pr products. In Australia, the expansion plans included improvements to the existing Mount Weld operation, relocating its crack and leach plant to Western Australia from Malaysia, and processing of mineral concentrates from the Duncan deposit (Lynas Corp. Ltd., 2019, p. 5). Mount Weld ore reserves were about 20 Mt containing 8.6% (1.7 Mt) REO. Total resources were about 55 Mt containing 5.4% (3.0 Mt) REO with about 69% of the total resource classified as measured and indicated (Lynas Corp. Ltd., 2018, p. 1–2).

Pilot-scale operations were ongoing at the Browns Range project in Western Australia. At yearend, the 3-year pilot study was one-half complete and had produced 159 t of rare-earth carbonate. Indicated resources for the Browns Range project were estimated to be 4.69 Mt containing about 0.7% (32,900 t) REO equivalent, using a cutoff grade of 0.15% REO. Probable reserves were 3.75 Mt containing about 0.7% (26,400 t) REO equivalent (Northern Minerals Ltd., 2015, p. 1, 2; 2020, p. 4).

Brazil.—Brazil exported an estimated 1,170 t of REE-bearing monazite concentrates to China in 2019, a decrease from 1,990 t exported in 2018. On a gross weight basis, the unit value of these exports was about $2,100 per metric ton (Zen Innovations AG, 2021).

Burundi.—Rainbow Rare Earths Ltd. continued its trial of mining and beneficiation at its Gakara project in Bujumbura Rural Province. For the fiscal year ending June 30, 2019, the company reported that 850 t of concentrate production was sold containing 57% REO. In 2020, the company expected to update its resource estimates with a target to support a 10-year mine life producing 10,000 t/yr of concentrate (Rainbow Rare Earths Ltd., 2019, p. 11, 12).

Canada.—In 2019, there were numerous companies with rare-earth projects under development in Canada. Total measured and indicated resources were estimated by the Canadian Government's Natural Resources Canada to be greater than 15 Mt of rare-earth oxides (Natural Resources Canada, 2021). In 2019, companies with projects known to have measured or indicated resources included Appia Energy Corp. (Elliot Lake), Avalon Advanced Materials Inc. (Nechalacho), Canada Rare Earth Corp. (Lavergne-Springer), Commerce Resources Corp. (Ashram), Defense Metals Corp. (Wicheeda), DNI Metals Inc. (Buckton), Geomega Resources Inc. (Montviel), Magris Resources Inc. (St-Honore), Quebec Precious Metals Corp. (Kipawa-Zeus), Search Minerals Inc. (Deep Fox), and Torngat Metals Ltd. (Strange Lake).

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 60% of global mine production in 2019. China's Ministry of Land and Resources (MRL) production quotas for rare-earth mine production were 132,000 t of REO equivalent, of which 112,850 t was for light rare earths and 19,150 t was for medium and heavy rare earths. The production quota for smelting and separation was 127,000 t. Nearly all mine, smelting, and separation quotas were allocated to the state-owned enterprises. The MRL continued efforts to prohibit illegal production and ensure compliance with environmental protection requirements (Ministry of Industry and Information Technology, 2019).

China's imports of rare-earth compounds under the Harmonized System (HS) code 2846 were about 41,000 t (gross weight) in 2019 compared with 69,500 t in 2018. Burma and

Malaysia were the leading import sources. China's imports of rare-earth metals (HS code 2805.30) were reported to be 26 t. China's imports of rare-earth ores (HS code 2530.90.20) were 46,700 t, almost entirely from the United States. On a gross weight basis, imports of thorium ores and concentrates (HS code 2612.20) containing REEs were 22,700 t, primarily from, in descending order, Madagascar, Thailand, Vietnam, and Brazil (Zen Innovations AG, 2021).

China's exports of rare-earth compounds (HS code 2846) were 39,500 t (gross weight), a 14% decrease compared with those in 2018. The top four destinations were the United States (38%), Japan (32%), the Netherlands (9%), and the Republic of Korea (6%). China's exports of rare-earth metals (HS code 2805.30) were 6,850 t, and Japan (59%) was the leading destination (Zen Innovations AG, 2021).

Greenland (Denmark).—Greenland Minerals and Energy Ltd. (GMEL) continued efforts to develop its polymetallic (REE-uranium-zinc) Kvanefjeld project in southern Greenland. In 2019, the company worked to improve its feasibility studies and obtain environmental permits. The Kvanefjeld project's ore reserves were reported to be 108 Mt containing 1.43% (1.54 Mt) REO. Measured and indicated resources were reported to be 451 Mt containing 1.14% (5.14 Mt) REO using a uranium-oxide cutoff grade of 0.015%. Measured and indicated resources were less than one-half of the total resources (Greenland Minerals and Energy Ltd., 2016, p. 8, 16; 2019, p. 4–10).

India.—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 the State of Kerala, IREL has capacity at Aluva to produce mixed rare-earth chlorides and separated compounds from monazite concentrates. At Chatrapur, in the State of Odisha, IREL was operating a processing plant that used monazite as a feedstock to produce up to 11,200 t/yr of mixed rare-earth chlorides. In fiscal year 2018–19, rare-earth chloride production was reported to be 4,215 t. No data were available for fiscal year 2019–20 (Indian Bureau of Mines, 2020, p. 24–3—24–4).

Japan.—The Japan Society of Newer Metals estimated the 2019 consumption of rare earths in Japan to be about 19,100 t, an increase compared with 18,600 t in 2018. Consumption included cerium (6,750 t), neodymium and praseodymium (4,650 t), mixed rare-earth metals (4,300 t), lanthanum (1,670 t), yttrium (1,080 t), other rare-earth compounds (565 t), samarium (80 t), and europium (10 t) (Japan Society of Newer Metals, 2020).

Madagascar.—In 2019, QIT Madagascar Minerals (QMM) produced monazite concentrates as a byproduct of processing heavy-mineral sands to produce ilmenite and zircon-sillimanite concentrates. QMM was owned by the Government of Madagascar (20%) and Rio Tinto plc (80%) (Rio Tinto plc, undated). In 2019, China imported about 16,000 t of monazite concentrates from Madagascar (Zen Innovations AG, 2021).

Malaysia.—Lynas continued production of rare-earth compounds at its Lynas Advanced Material Plant (LAMP) near the Port of Kuantan in the State of Pahang. Although the production of Nd-Pr compounds remained level, the overall production of REO in compounds from the LAMP operations in 2019 was about 17,600 t, a 5% decrease compared with production in 2018. The overall decrease in the production of compounds was caused in part by regulatory limits on the processing of concentrates (Lynas Corp. Ltd., 2020b).

Philippines.—Japan's Sumitomo Metal Mining Co., Ltd. (SMM) began commercial-scale production of 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 began in 2019 and was performed at SMM's Harima operation in Japan (Sumitomo Metal Mining Co., Ltd., 2018, p. 15, 26; 2020, p. 53).

Russia.—Imports of rare-earth compounds (HS code 2846) into Russia were about 1,260 t in 2019, and exports were 6,210 t. Rare-earth-metal (HS code 2805.30) imports and exports were 70 t and 2 t, respectively. China and Estonia were Russia's leading import sources, and Estonia and India were the leading export destinations of rare-earth compounds (Zen Innovations AG, 2021).

JSC Solikamsk Magnesium Works (SMW) in Perm Krai reported consumption of about 9,500 t of loparite concentrates sourced from mining operations near Revda in the Murmansk Region. SMW reported that shipments of rare-earth compounds were about 2,600 t of REO equivalent in 2019. SMW was 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, 2020, p. 4–15).

South Africa.—Steenkampskraal Holdings Ltd. continued plans to reopen the Steenkampskraal (SKK) monazite mine that was active from 1952 to 1963. The company expected to produce up to 2,700 t/yr of REO equivalent in mixed carbonates. In 2019, the company reported that it had received the water license needed to fully permit construction and mining. Using a 1%-REO cutoff grade, SKK's measured and indicated resources were reported to be 605,000 t containing about 14.4% (86,900 t) of REO equivalent (Steenkampskraal Monazite Mine (Pty) Ltd., 2019).

Sweden.—In August, Leading Edge Materials Corp. requested an extension on the exploration license for its Norra Karr mining project. At yearend, the permit was valid until the completion of a review by the Swedish Government. Probable reserves for the project were previously reported to be 23.6 Mt containing 0.592% (140,000 t) REO equivalent. Using a 0.4%-REO cutoff grade, indicated resources were 31.1 Mt containing 0.61% (190,000 t) REO equivalent. The predominate REE mineralization was eudialyte. A prefeasibility study was based on a production of about 5,000 t/yr of mixed REO and a 20-year mine life, using the 0.4%-REO cutoff grade (Tasman Metals Ltd., 2015, p. 42–43, 45; Leading Edge Materials Corp., 2020, p. 6).

Tanzania.—Peak Resources Ltd. continued the development of its Ngualla project with plans for mining operations in southwest Tanzania. Reserves were reported to be 18.5 Mt of ore containing 4.8% (887,000 t) of REO equivalent. Resources were reported to be about 210 Mt containing 2.2% (4.6 Mt) REO and 93% of the resources were classified as measured and indicated using a 1% cutoff grade. Peak Resources expected the Ngualla operations to produce up to 32,700 t/yr of mineral concentrate. At yearend, a special mining license was pending approval by the Tanzania's Minister of Minerals (Peak Resources Ltd., 2018, p. 69–71; 2020, p. 3).

United Kingdom.—In 2019, Peak Resources continued plans to construct its Teesside extraction and separation operations located in the Wilton industrial area near Middleborough. The company expected that the Teesside operation would process up to 32,700 t/yr of concentrates from its Ngualla mining operations and produce mixed and separated REO compounds (Peak Resources Ltd, 2020, p. 3, 5).

Outlook

The annual average growth rate of REE consumption is expected to range from 5% to 10% through 2025. The leading end uses of rare earths are expected to be magnets, catalysts, and polishing compounds, in descending order of quantity. The magnet materials sector is expected to have higher average growth, and the catalysts, ceramics, 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 shape the global markets for rare-earth compounds and metal alloys. China's imports of mineral concentrates are expected to continue to significantly increase.

References Cited

Defense Logistics Agency Strategic Materials, 2019, Annual Materials Plan for FY 2020: Fort Belvoir, VA, Defense National Stockpile Center news release DLA–SM–20–3167, October 4, 1 p. (Accessed August 12, 2021, at https://www.dla.mil/Portals/104/Documents/Strategic%20Materials/Announcements/3167%20FY20%20AMP_ACQ.pdf?ver=2019-10-04-090806-880.)

Geoscience Australia, 2021, Australia's identified mineral resources 2020: Canberra, Australian Capital Territory, Australia, Geoscience Australia, February 4, 81 p. (Accessed October 14, 2021, at https://d28rz98at9flks.cloudfront.net/144533/144533_00_3.pdf.)

Greenland Minerals and Energy Ltd., 2016, Raw materials for a clean and energy efficient future—2015 annual report: Subiaco, Western Australia, Australia, Greenland Minerals and Energy Ltd., March 30, 77 p. (Accessed October 14, 2021, at https://www.ggg.gl/assets/Uploads/Annual-Reports/e3721988ca/2015-Annual-Report.pdf.)

Greenland Minerals and Energy Ltd., 2019, Materials for an energy efficient future—2019 annual report: Subiaco, Western Australia, Australia, Greenland Minerals and Energy Ltd., March 29, 70 p. (Accessed October 14, 2021, at https://wcsecure.weblink.com.au/pdf/GGG/02219702.pdf.)

Iluka Resources Ltd., 2019, Eneabba mineral sands recovery project—Updated mineral resource estimate: Perth, Western Australia, Australia, Iluka Resources Ltd., July 24, 18 p. (Accessed October 12, 2021, at https://iluka.com/getattachment/0a5e3a12-e4ea-4966-9d07-ba924642de95/eneabba-mineral-sands-recovery-project-update.aspx.)

Indian Bureau of Mines, 2020, Rare earths, *in* Part III—Mineral reviews (58th ed.) (advance release): Nagpur, India, Indian Minerals Yearbook 2019, v. III, September, p. 24–1 to 24–10. (Accessed October 5, 2021, at https://ibm.gov.in/writereaddata/files/10012020172151RareEarth_2019_AR.pdf.)

Japan Society of Newer Metals, 2020, Demand for rare earths in 2019: Tokyo, Japan, Japan Society of Newer Metals, March 24. (Accessed October 5, 2021, via http://www.jsnm.or.jp/news/?p=1253.)

JSC Solikamsk Magnesium Works, 2020, Annual report 2019: Solikamsk, Russia, JSC Solikamsk Magnesium Works, June 18, 38 p. (Accessed October 12, 2021, via https://smw.ru/shareholder/everyear.)

Leading Edge Materials Corp., 2020, Management's discussion and analysis for the three months ended January 31, 2020: Vancouver, British Columbia, Canada, Leading Edge Materials Corp., March 26, 14 p. (Accessed October 13, 2021, via https://www.sedar.com/.)

Lynas Corp. Ltd., 2018, Lynas announces a 60% increase to Mt Weld ore reserves, one of the world's richest sources of rare earths: East Perth, Western Australia, Australia, Lynas Corp. Ltd., August 6, 29 p. (Accessed October 6, 2021, at https://www.lynascorp.com/wp-content/uploads/2019/05/180806-Resources-and-Reserves-Update-2018-1827684.pdf.)

Lynas Corp. Ltd., 2019, Lynas 2025—Growing with the market: East Perth, Western Australia, Australia, Lynas Corp. Ltd. presentation, May 21, 70 p. (Accessed October 6, 2021, at https://lynasrareearths.com/wp-content/uploads/2019/05/190521-Investor-Day-Presentation-Lynas-2025-1931391.pdf.)

Lynas Corp. Ltd., 2020a, Lynas / Blue Line MOU for rare earths separation capacity in the United States: East Perth, Western Australia, Australia, Lynas Corp. Ltd. news release, May 20. (Accessed September 30, 2021, at https://wcsecure.weblink.com.au/pdf/LYC/02106823.pdf.)

Lynas Corp. Ltd., 2020b, Quarterly report for the period ending 31 December 2019: East Perth, Western Australia, Australia, Lynas Corp. Ltd., January 23, 8 p. (Accessed October 6, 2021, at https://wcsecure.weblink.com.au/pdf/LYC/02195169.pdf.)

Mason, Brian, and Moore, Carleton, 1982, Principles of geochemistry (4th ed.): New York, NY, John Wiley & Sons, 344 p.

Ministry of Industry and Information Technology, 2019, Notice of the Ministry of Industry and Information Technology of the Ministry of Natural Resources on issuing the 2019 rare earth mining, smelting and separation total control index and tungsten mining total control index: Beijing, China, Ministry of Industry and Information Technology, October 31. (Accessed October 4, 2021, at https://www.miit.gov.cn/jgsj/ycls/wjfb/art/2020/art_bdf450bdec0644eebcff9cd396ef0a3c.html.) [In Chinese.]

National Energy Technology Laboratory, 2019, 2019 science & technology accomplishments: National Energy Technology Laboratory, March 1, 95 p. (Accessed August 12, 2021, via https://netl.doe.gov/accomplishments/2019.)

National Science Foundation, 2019, SBIR Phase II—Sustainable rare earth element recycling from neodymium magnets: National Science Foundation award abstract #1632711, June 29. (Accessed August 12, 2021, at https://www.nsf.gov/awardsearch/showAward?AWD_ID=1632711.)

Natural Resources Canada, 2021, Rare earth elements facts: Ottawa, Ontario, Canada, Natural Resources Canada, February 3. (Accessed October 13, 2021, at https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/rare-earth-elements-facts/20522.)

NioCorp Developments Ltd., 2017, Revised NI 43–101 technical report feasibility study Elk Creek niobium project Nebraska: Centennial, CO, NioCorp Developments Ltd., December 15, 466 p. plus appendices. (Accessed February 14, 2019, via https://www.sedar.com/.)

NioCorp Developments Ltd., 2020, Form 10–Q—For the quarterly period ended December 31, 2019: U.S. Securities and Exchange Commission, 24 p. (Accessed September 21, 2021, at https://www.sec.gov/Archives/edgar/data/1512228/000121390020002835/f10q1219_niocorpdevelop.htm.)

Northern Minerals Ltd., 2015, Increased ore reserve for Browns Range project: West Perth, Western Australia, Australia, Northern Minerals Ltd., Australian Securities Exchange announcement, March 2, 18 p. (Accessed October 6, 2021, via https://northernminerals.com.au/asx-announcements/.)

Northern Minerals Ltd., 2020, Quarterly activities report—December 2019: West Perth, Western Australia, Australia, Northern Minerals Ltd., March 13, 29 p. (Accessed October 6, 2021, via https://northernminerals.com.au/news-reports-presentations/#halfyearlyreports.)

Peak Resources Ltd., 2018, Annual report 2018: West Perth, Western Australia, Australia, Peak Resources Ltd., October 10, 76 p. (Accessed October 13, 2021, at https://wcsecure.weblink.com.au/pdf/PEK/02033178.pdf.)

Peak Resources Ltd., 2020, Half year report 31 December 2019: West Perth, Western Australia, Australia, Peak Resources Ltd., March 11, 23 p. (Accessed October 13, 2021, at https://wcsecure.weblink.com.au/pdf/PEK/02213057.pdf.)

Rainbow Rare Earths Ltd., 2019, Annual report 2019: St. Peter Port, Guernsey [United Kingdom], Rainbow Rare Earths Ltd., October 30, 67 p. (Accessed October 1, 2021, at https://rainbowrareearths.com/wp-content/uploads/2019/10/RBW-2019-Annual-Report-website.pdf.)

Rare Element Resources Ltd., 2018, Form 10–K—2017: U.S. Securities and Exchange Commission, March 26, 73 p. (Accessed January 21, 2021, at https://www.sec.gov/Archives/edgar/data/1419806/000105291818000086/rer10kmar26-18v2.htm.)

Rare Element Resources Ltd., 2020, Form 10–K—2019: U.S. Securities and Exchange Commission, March 17, 61 p. (Accessed September 29, 2021, at https://www.sec.gov/Archives/edgar/data/1419806/000105291820000052/rer10kmar17-20.htm#_Toc509922493.)

Rio Tinto plc, [undated], QIT Madagascar Minerals: London, United Kingdom, Rio Tinto plc. (Accessed October 6, 2021, at https://www.riotinto.com/en/operations/madagascar/qit-madagascar-minerals.)
Steenkampskraal Monazite Mine (Pty) Ltd., 2019, Steenkampskraal rare earths mine obtains water license: Strand, Western Cape, South Africa, Steenkampskraal Holdings Ltd., November 20. (Accessed October 12, 2021, at https://www.steenkampskraal.com/steenkampskraal-rare-earths-mine-obtains-water-license/.)
Sumitomo Metal Mining Co., Ltd., 2018, Integrated report 2018: Tokyo, Japan, Sumitomo Metal Mining Co., Ltd., November, 173 p. (Accessed October 12, 2021, via https://www.smm.co.jp/en/ir/library/integrated_report/.)
Sumitomo Metal Mining Co., Ltd., 2020, Integrated report 2020: Tokyo, Japan, Sumitomo Metal Mining Co., Ltd., November, 137 p. (Accessed October 12, 2021, via https://www.smm.co.jp/ir/library/integrated_report/.)
Tasman Metals Ltd., 2015, Form 20–F—For the fiscal year ended August 31, 2015: U.S. Securities and Exchange Commission, November 30, 116 p. (Accessed October 14, 2021, at http://www.sedar.com/GetFile.do?lang=EN&docClass=2&issuerNo=00029095&issuerType=03&projectNo=02424798&docId=3837116.)
Texas Mineral Resources Corp., 2014, Amended NI 43–101 preliminary economic assessment Round Top project: Sierra Blanca, TX, Texas Mineral Resources Corp., April 28, 197 p. (Accessed September 30, 2021, at http://tmrcorp.com/_resources/reports/Amended_TRER_NI43-101_PEA_FINAL_28April2014.pdf.)
Texas Mineral Resources Corp., 2020, Form 10–Q for the quarterly report ended February 29, 2020: Sierra Blanca, TX, Texas Mineral Resources Corp., February 29, 20 p. (Accessed September 30, 2021, at http://tmrcorp.com/_resources/financials/TMRC-02-29-20-Q-Final.pdf.)
Ucore Rare Metals Inc., 2020, Management's discussion and analysis for the year ended December 31, 2019: Bedford, Nova Scotia, Canada, Ucore Rare Metals Inc., April 29, 37 p. (Accessed September 30, 2021, via https://www.sedar.com/.)
U.S. Department of Defense Industrial Policy, 2020, Fiscal year 2019 industrial capabilities—Report to Congress: Washington, DC, U.S. Department of Defense Industrial Policy, June 23, 172 p. (Accessed January 31, 2022, at https://www.businessdefense.gov/docs/resources/USA000954-20_RPT_Subj_FY19_ICR_07092020.pdf.)
U.S. Department of Energy, 2019, The Critical Materials Institute—An energy innovation hub: U.S. DOE Advanced Manufacturing Office program review meeting, Washington, DC, June 11, 29 p. (Accessed January 11, 2021, at https://www.energy.gov/sites/prod/files/2019/07/f64/003-Consortia19%20-%20Critical%20Materials%20Institute.pdf.)
U.S. Small Business Administration, 2021, Award database: Washington, DC, U.S. Small Business Administration. (Accessed August 12, 2021, via https://www.sbir.gov/sbirsearch/award/all/rare%20earth?f%5B0%5D=im_field_agencies%3A105731&f%5B1%5D=itm_field_award_yr%3A2019.)
Zen Innovations AG, 2021, Global trade tracker: Bern-Kehrsatz, Switzerland, Zen Innovations AG database. (Accessed October 12, 2021, via https://www.globaltradetracker.com.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
Rare-Earth Elements. Ch. in Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, 2017.
Rare-Earth Metals (Ce, Dy, Eu, Gd, La, Nd, Pr, Sm, Sc, Tb, Y). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.
Rare-Earth Oxides. International Strategic Minerals Inventory Summary Report, Circular 930–N, 1993.
Rare Earths. Ch. in Mineral Commodity Summaries, annual.
Scandium. Ch. in Mineral Commodity Summaries, annual.
Thorium. Ch. in Mineral Commodity Summaries, annual.
Thorium. Ch. in Minerals Yearbook, annual.
Yttrium. Ch. in Mineral Commodity Summaries, annual.

Other

China Rare Earth Information (newsletter), monthly.
Industrial Minerals, monthly.
Metal Bulletin, weekly.
Rare Earth Elements and Yttrium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Rare Earth Market Outlook to 2030. Adamas Intelligence, 2020.
Rare Earths. Ch. in Industrial Minerals and Rocks—Commodities, Markets, and Uses, Society for Mining, Metallurgy, and Exploration Inc., 7th ed., 2006.
Rare Earths—Outlook to 2029. Roskill Information Services Ltd., 2019.

TABLE 1

SALIENT U.S. RARE EARTH STATISTICS[1]

		2015	2016	2017	2018	2019
Production of rare-earth concentrates, rare-earth-oxide (REO) equivalent[e, 2, 3]	metric tons	5,900	--	--	14,000	28,000
Exports, REO equivalent:[e]						
Rare-earth concentrates, monazite	do.	--	--	--	260 r	840
Compounds:						
Cerium compounds	do.	440	309	1,140	304	208
Other rare-earth compounds	do.	4,540	281	598 r	17,300	27,100
Metals:						
Ferrocerium and pyrophoric alloys	do.	1,220	943	982	1,250	1,290
Rare-earth metals, scandium, yttrium	do.	60	103	55	28	83
Imports for consumption, REO equivalent:[e]						
Compounds:						
Cerium compounds	do.	1,440	1,830	2,390 r	2,940	2,510
Other rare-earth compounds	do.	7,720	9,650	8,600 r	7,890	9,800
Metals:						
Ferrocerium and pyrophoric alloys	do.	356	268	309	298	332
Rare-earth metals, scandium, yttrium	do.	385	404	524	526	627
World production, REO equivalent	do.	129,000	133,000	147,000	190,000	219,000
Prices, annual average:						
Monazite concentrate, gross basis[e]	dollars per kilogram	2.56	2.57	2.70	2.40 r	2.60
Mischmetal, 65% cerium, 35% lanthanum, metal basis[4]	do.	6.93	5.17	5.51	6.16	5.82

[e]Estimated. [r]Revised. do. Ditto. -- Zero.

[1]Table includes data available through January 26, 2021. Data are rounded to no more than three significant digits.

[2]Includes only the rare earths derived from bastnaesite.

[3]Sources: Molycorp, Inc., 2015, Form 10–Q—For the quarterly period ending June 30, 2015: U.S. Securities and Exchange Commission, 71 p.; MP Materials Corp., 2020, Prospectus: U.S. Securities and Exchange Commission, 149 p.

[4]Source: Argus Media group – Argus Metals International.

TABLE 2
RARE EARTH CONTENTS OF SELECTED SOURCE MINERALS[1, 2]

(Percentage of total rare-earth oxide)

			Rare-earth-element symbol														
Primary source	Country	Location	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
Bastnaesite	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	NA	NA	NA	NA	NA	0.50
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	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	0.70
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	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	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	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	0.00	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	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	0.45
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	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	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	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	59.30

Do., do. Ditto. NA Not available.

[1]Table includes data available through July 7, 2020. Rows may not add to 100 percent.

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

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

[4]Source: Zhi Li, Ling, and Yang, Xiaosheng, 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.

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

[6]Source: Hedrick, 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.

[7]Source: Lynas 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.

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

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

TABLE 3

RARE-EARTH OXIDE PRICES[1]

Product (oxide)	Purity (percent)	Price (dollars per kilogram) 2018	2019
Scandium[2]	99.990	4,600	3,900
Yttrium[3]	99.999	3	3
Lanthanum[3]	99.500	2	2
Cerium[3]	99.500	2	2
Praseodymium[3]	99.500	63	54
Neodymium[3]	99.500	50	45
Samarium[3]	99.500	2	2
Europium[3]	99.990	53	35
Gadolinium[3]	99.999	44	46
Terbium[3]	99.990	455	507
Dysprosium[3]	99.500	179	239

[1]Products are listed in order of atomic number.

[2]Source: Stanford Metals Corp.

[3]Source: Argus Media group – Argus Metals International.

TABLE 4

U.S. EXPORTS OF RARE-EARTH COMPOUNDS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2018 Gross weight (kilograms)	2018 Value	2019 Gross weight (kilograms)	2019 Value
Cerium compounds:	2846.10.0000				
Austria		32,300	$433,000	10,300	$135,000
Canada		7,150	260,000	23,900	362,000
China		26,500	1,120,000	20,100	1,170,000
Germany		37,300	1,050,000	38,000	1,030,000
Japan		35,600	431,000	21,500	322,000
Korea, Republic of		136,000	1,650,000	26,700	283,000
Mexico		8,480	130,000	8,300	52,100
Norway		--	--	16,800	16,800
South Africa		11,900	167,000	12,100	152,000
Taiwan		96,000	666,000	104,000	554,000
Thailand		18,800	173,000	6,820	89,300
Other		44,400 r	10,400,000 r	22,100	661,000
Total		455,000	16,400,000	311,000	4,820,000
Total estimated rare-earth-oxide (REO) equivalent content		304,000	XX	208,000	XX
Other rare-earth compounds:					
Oxides:					
Scandium or yttrium oxides:	2846.90.2015				
Finland		4,090	19,500	--	--
Germany		7,480	315,000	4,990	168,000
Mexico		2,000	6,670	--	--
Other		503	142,000	786	130,000
Total		14,100	484,000	5,770	298,000
Total estimated REO equivalent content		14,100	XX	5,770	XX
Other oxides:	2846.90.2040				
Finland		6,190	29,500	--	--
Japan		--	--	60,900	458,000
Switzerland		3,650	2,490,000	2,260	1,670,000
Other		2,900 r	894,000 r	4,710	610,000
Total		12,700	3,410,000	67,800	2,730,000
Total estimated REO equivalent content		12,700	XX	67,800	XX
Chlorides:	2846.90.2060				
Colombia		15,300	18,900	--	--
Jordan		40,100	53,200	--	--
Kuwait		14,600	19,500	--	--
Other		4,020 r	57,900 r	3,640	476,000
Total		74,000	149,000	3,640	476,000
Total estimated REO equivalent content		34,000	XX	1,670	XX
Unspecified rare-earth compounds:	2846.90.9000				
China		32,600,000	71,600,000	45,600,000	65,200,000
Other		411,000	8,270,000	331,000	9,540,000
Total		33,000,000	79,900,000	45,900,000	74,700,000
Total estimated REO equivalent content		17,200,000 r	XX	27,000,000	XX
Grand total		33,600,000	100,000,000 r	46,300,000	83,100,000
Grand total estimated REO equivalent content		17,600,000	XX	27,300,000	XX

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

[1]Table includes data available through June 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS OF RARE-EARTH METALS AND ALLOYS, BY COUNTRY OR LOCALITY[1]

		2018		2019	
Category and country or locality	HTS[2] code	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Ferrocerium and other pyrophoric alloys:	3606.90.0000				
Aruba		18,900	$31,200	27,400	$42,300
Australia		7,590	54,700	26,000	3,000,000
Barbados		48,200	112,000	26,000	82,600
Canada		394,000	1,260,000	298,000	1,240,000
China		12,700	529,000	43,800	1,970,000
Colombia		18,000	97,400	17,300	62,600
Costa Rica		40,900	121,000	56,000	150,000
Dominican Republic		27,700	51,200	35,000	54,700
Haiti		31,600	40,400	19,300	31,600
Honduras		208,000	230,000	356,000	417,000
Israel		--	--	38,900	41,100
Jamaica		9,500	36,500	64,200	114,000
Japan		15,000	981,000	20,300	1,200,000
Mexico		159,000	602,000	23,100	109,000
Panama		75,600	126,000	71,700	147,000
Thailand		57	12,500	36,300	12,900
Trinidad and Tobago		35,300	54,500	71,300	124,000
United Kingdom		167,000	962,000	91,100	557,000
Other		143,000 r	4,410,000 r	131,000	2,180,000
Total		1,410,000	9,710,000	1,450,000	11,500,000
Total estimated rare-earth-oxide (REO) equivalent content		1,250,000	XX	1,290,000	XX
Rare-earth metals and alloys:	2805.30.0000				
Austria		--	--	1,680	84,600
Brazil		386	21,300	15,200	30,700
China		2,210	208,000	19,900	232,000
Japan		3,100	188,000	3,080	156,000
United Kingdom		10,700	2,010,000	22,300	402,000
Other		5,440 r	683,000 r	3,060	714,000
Total		21,800	3,110,000	65,200	1,620,000
Total estimated REO equivalent content		27,700	XX	82,800	XX

[r]Revised. XX Not applicable. -- Zero.
[1]Table includes data available through June 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF RARE-EARTH COMPOUNDS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2018 Gross weight (kilograms)	2018 Value	2019 Gross weight (kilograms)	2019 Value
Cerium oxides:	2846.10.0010				
China		275,000	$2,420,000	225,000	$1,430,000
Japan		389,000	17,900,000	530,000	23,600,000
Other		22,600	690,000	15,000	566,000
Total		687,000	21,000,000	770,000	25,600,000
Total estimated rare-earth-oxide (REO) equivalent content		687,000	XX	770,000	XX
Cerium compounds, other than cerium oxide:	2846.10.0050				
China		2,400,000	9,530,000	1,870,000	6,460,000
Estonia		676,000	1,860,000	646,000	1,460,000
Other		295,000	1,410,000	82,300	878,000
Total		3,370,000	12,800,000	2,600,000	8,790,000
Total estimated REO equivalent content		2,260,000	XX	1,740,000	XX
Other rare-earth compounds:					
Carbonates:					
Lanthanum carbonates mixtures:	2846.90.8070				
China		219,000	989,000	323,000	1,180,000
Other		30	22,500	1,020	22,300
Total		219,000	1,010,000	324,000	1,200,000
Total estimated REO equivalent content		150,000	XX	222,000	XX
Other rare-earth carbonates mixtures:	2846.90.8075				
China		5,690	464,000	5,100	372,000
Germany		--	--	--	--
Total		5,690	464,000	5,100	372,000
Total estimated REO equivalent content		3,130	XX	2,810	XX
Chlorides:					
Scandium or yttrium chloride mixtures:	2846.90.2082				
Canada		4,000	15,600	--	--
China		4,030	24,400	--	--
Other		31	12,000	--	--
Total		8,060	52,000	--	--
Total estimated REO equivalent content		2,980	XX	--	XX
Unspecified mixtures of oxides or chlorides:	2846.90.2084				
China		832,000	2,270,000	1,120,000	2,630,000
Other		44,900	1,690,000	36,900	1,400,000
Total		877,000	3,960,000	1,150,000	4,030,000
Total estimated REO equivalent content		483,000	XX	634,000	XX
Oxides:					
Lanthanum oxides:	2846.90.2005				
China		1,400,000	3,560,000	759,000	1,910,000
Other		11,700	75,800	121,000	2,500,000
Total		1,410,000	3,640,000	881,000	4,410,000
Total estimated REO equivalent content		1,410,000	XX	881,000	XX
Scandium or yttrium oxides:	2846.90.2015				
China		10,100	265,000	18,800	389,000
Japan		2,140	724,000	1,270	362,000
Korea, Republic of		3,520	659,000	3,330	729,000
Other		996 r	197,000 r	2,050	226,000
Total		16,800	1,850,000	25,400	1,700,000
Total estimated REO equivalent content		16,800	XX	25,400	XX
Other oxides:	2846.90.2040				
China		118,000	4,420,000	98,900	5,440,000
Russia		3,500	103,000	59,900	187,000
Other		19,200 r	973,000 r	9,340	596,000
Total		140,000	5,490,000	168,000	6,220,000
Total estimated REO equivalent content		140,000	XX	168,000	XX

See footnotes at end of table.

TABLE 6—Continued

U.S. IMPORTS FOR CONSUMPTION OF RARE-EARTH COMPOUNDS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2018 Gross weight (kilograms)	2018 Value	2019 Gross weight (kilograms)	2019 Value
Other rare-earth compounds:					
Other rare-earth compounds or mixtures:					
Unspecified compounds or mixtures:	2846.90.8090				
China		8,140,000	$60,600,000	11,000,000	$63,500,000
Malaysia		857,000	3,390,000	1,850,000	4,100,000
Other		1,060,000 r	29,800,000 r	1,130,000	23,300,000
Total		10,100,000	93,800,000	14,000,000	90,900,000
Total estimated REO equivalent content		5,530,000	XX	7,680,000	XX
Yttrium materials and compounds content by weight greater than 19% but less than 85% oxide equivalent:	2846.90.4000				
China		252,000	1,240,000	305,000	759,000
Other		914	1,580,000	4,640	1,940,000
Total		253,000	2,820,000	310,000	2,700,000
Total estimated REO equivalent content		152,000	XX	186,000	XX

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

[1]Table includes data available through June 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF RARE-EARTH METALS AND ALLOYS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2018 Gross weight (kilograms)	2018 Value	2019 Gross weight (kilograms)	2019 Value
Ferrocerium and other pyrophoric alloys:	3606.90.3010 and 3606.90.3090				
Austria		54,300	$552,000	36,900	$423,000
China		99,500	1,300,000	162,000	1,720,000
Spain		136,000	2,440,000	139,000	2,440,000
United Kingdom		30,900	170,000	10,500	54,100
Other		15,500	179,000	24,900	255,000
Total		336,000	4,640,000	374,000	4,900,000
Total estimated rare-earth-oxide (REO) equivalent content		298,000	XX	332,000	XX
Rare-earth metals and alloys:					
Cerium, unalloyed:	2805.30.0010				
China		71,000	617,000	100,000	843,000
Hong Kong		--	--	180,000	936,000
United Kingdom		515	27,500	--	--
Total		71,500	645,000	280,000	1,780,000
Total estimated REO equivalent content		87,900	XX	344,000	XX
Lanthanum, unalloyed:	2805.30.0005				
China		70,700	1,310,000	105,000	1,500,000
Other		2,480	204,000	167	13,300
Total		73,100	1,520,000	105,000	1,520,000
Total estimated REO equivalent content		85,800	XX	123,000	XX
Neodymium, unalloyed:	2805.30.0020				
China		7,260	338,000	2,480	361,000
Japan		--	--	83	7,000
United Kingdom		350	51,200	--	--
Total		7,610	390,000	2,560	368,000
Total estimated REO equivalent content		8,870	XX	2,990	XX
Other rare-earth metals, unalloyed:	2805.30.0050				
China		46,800	1,570,000	29,200	1,150,000
Russia		9,310	743,000	10,100	808,000
Other		668	91,200	55	16,300
Total		56,800	2,400,000	39,300	1,970,000
Total estimated REO equivalent content		68,200	XX	47,200	XX
Other rare-earth metals, alloys:	2805.30.0090				
China		222,000	2,120,000	81,200	1,710,000
Other		7,670	684,000	10,100	848,000
Total		230,000	2,810,000	91,300	2,560,000
Total estimated REO equivalent content		275,000	XX	110,000	XX
Grand total		775,000	12,400,000	893,000	13,100,000
Grand total estimated REO equivalent content		824,000	XX	959,000	XX

XX Not applicable. -- Zero.

[1]Table includes data available through June 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 8
RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons, rare-earth-oxide equivalent)

Country or locality[2]	2015	2016	2017	2018	2019
Australia[e]	12,000	15,000	19,000	21,000	20,000
Brazil[e]	--	2,700	1,700	1,200	710
Burma[e]	370	3,500	15,000	23,000	25,000
Burundi[e]	--	--	40	620	200
China[3]	105,000	105,000	105,000	120,000	132,000
India[4]	1,700	1,500	1,800	2,900	2,900
Madagascar[e]	--	--	--	2,000	4,000
Malaysia[e]	310	1,100	180	990	66
Russia	2,500 [e]	2,700	2,700	2,700	2,700 [e]
Thailand[e, 5]	760	1,600	1,300	1,000	1,900
United States[e]	5,900	--	--	14,000	28,000
Vietnam[e, 5]	270	240	220	920	1,300
Total	129,000	133,000	147,000	190,000	219,000

[e]Estimated. -- Zero.
[1]Table includes data available through January 26, 2021. 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.
[2]In addition to the countries and (or) localities listed, Indonesia, North Korea, Nigeria, and some Commonwealth of Independent States countries may have produced rare-earth minerals, but available information was inadequate to make reliable estimates of output.
[3]Official production quota. Illegal production could not be quantified.
[4]India's Department of Atomic Energy did not disclose monazite production data.
[5]Rare-earth-oxide content of exports.