University of Wyoming | School of Energy Resources

An Analysis of the Current Global Market for Rare Earth Elements

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DEFINITIONS AND TERMS

Bear Lodge Deposit – the proven REE deposit located in Wyoming, owned by Rare Element Resources

CM – Critical Mineral(s)

DOD – United States Department of Defense

DOE – United States Department of Energy

DOI – United States Department of the Interior

kg – kilogram

kt – kiloton, 1,000 tons

mt – metric ton, 1,000 kg, tonne

mt REO – REO content weight in mt

REE – Rare Earth Element(s)

REE Mixed Concentrate – the remaining mass of material containing REE after any part of the initial beneficiation process before being separated into individual streams of REE purity products

REE Purity Product – Rare Earth Oxides, Rare Earth Metals, Rare Earth alloys, or mischmetal

REE Supply Chain – The global REE mining and separations and concentrations industry up to the point of sales of REE purity products to downstream consumers

REE Value Chain – The entirety of the global REE industry, encompassing the Global Supply Chain and end-use consumption

REM – Rare Earth Metal(s)

REO – Rare Earth Oxide(s)

TREO – Total Rare Earth Oxide, represented as a percentage to quantify REE concentration in a mass of material such as a deposit, an REE mixed concentrate, or marketed purity products

USGS – United States Geological Survey

WSGS – Wyoming Geological Survey

EXECUTIVE SUMMARY

This paper is the first in a two-part series focusing on the rare earth element (REE) industry (when referred to in the papers, the term “REE” represents the plural or the singular, as implied by sentence context). Due to the unique characteristics of REE and complexities that characterize the REE market, this paper aims to provide a base understanding of REE, the REE production and extraction process, and an overview of the global REE market. Given that the US imports all the REE it consumes from foreign countries, government interest in locally sourced REE has grown. This paper provides a summary of US government interest, policies, and funding being directed to the study and development of a REE supply chain in the US.

In the narrower context of Wyoming’s REE resource potential, the second paper will explore the implications of the market issues identified in this paper, identify barriers to developing a fully integrated REE supply chain in Wyoming, and examine various policy solutions to support the establishment of a viable REE supply chain in Wyoming. The second paper will consider the proven Bear Lodge deposit as well as unconventional sources of REE in the state.

Often the terms critical minerals (CM) and REE are used interchangeably. For purposes of this paper, CM are minerals or mineral groups that have been identified by the Secretary of the Interior, through the Director of the US Geological Survey (USGS), as vital to the economic and national security of the United States; REE are a sub-set of CM.[1] The USGS published an updated CM list in May 2021[2] and the final proposed list was posted in November of 2021.[3]

REE are a unique set of seventeen different metals that occur naturally as soft metals. REE differ from other mined metals in that all seventeen occur together as a group, and concentrations large enough to economically mine and extract are uncommon. REE are sometimes referred to as oxides, even though their mineral occurrence may not be in the form of an oxide.[4] Much of the literature on REE highlight the fact that REE are not actually rare, and in fact, are ubiquitous in the earth’s crust. The “rare” aspect of REE is finding and identifying economically exploitable deposits – resources containing concentrations of REE large enough that make their extraction profitable under existing market conditions.

Currently, global REE production is primarily sourced from hard rock mineral deposits and ion-absorption clays. Because REE are ubiquitous in the earth’s crust, REE can also be recovered as a by-product of a different primary mined resource, like zirconium, or from unconventional sources of REE like coal overburden or coal fly ash.

REE are not usable until purified and separated into individual oxide or metal form; however, the process required to separate individual REE and render them usable is expensive, environmentally hazardous, and chemically intensive.

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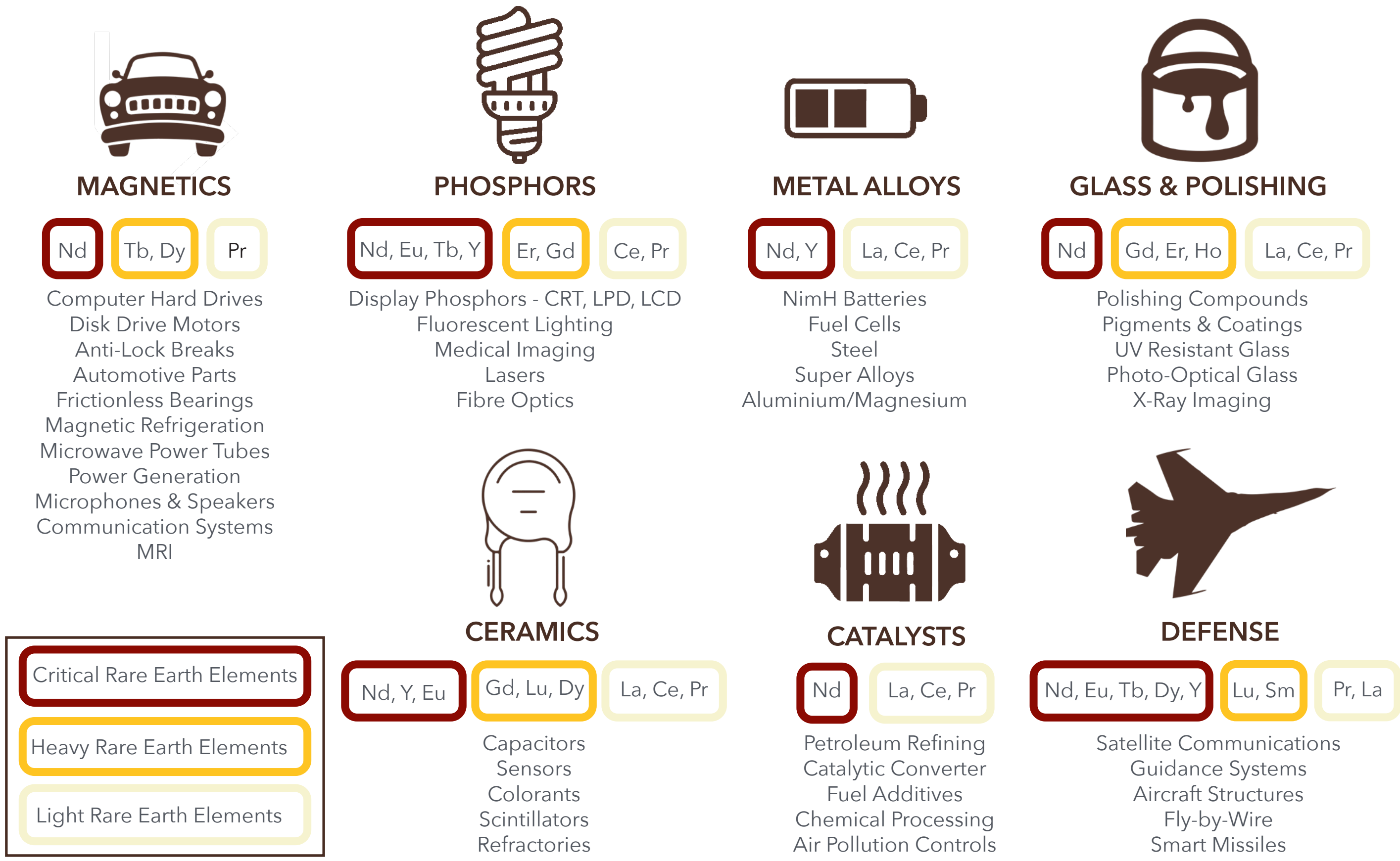
[1] The Energy Act of 2020 provides a definition of “critical minerals.”
[2] https://pubs.er.usgs.gov/publication/ofr20211045.
[3] https://www.federalregister.gov/documents/2021/11/09/2021-24488/2021-draft-list-of-critical-minerals.
[4] Sutherland, W.M. and Cola, E.C., 2016, A comprehensive report on rare earth elements in Wyoming: Wyoming State Geological Survey Report of Investigations No. 71, 137 p. 4.

REE are a critical component of many different end-use products and do not serve a purpose as a stand-alone product like other mined metals such as the precious metals gold and silver. REE are in hundreds of manufactured products. Most of the products that employ REE are produced in China or in the surrounding Asia Pacific region. Applications of REE in end-use products are shown in Image 1 below:

Image 1: Rare Earth Element Key Applications



Rare Earth Element Key Applications[5]

As demand increases for the end-use products that require REE in their manufacturing, REE consumption increases.

Global demand for REE has increased over time and is projected to increase significantly driven by permanent magnet demand growth. Permanent magnets are required to make technological goods, such as computer hard drives, power generators, and motors operational. Demand for permanent magnets is growing. In March 2021, Adamas Intelligence reported the following high-level findings from its Rare Earth Magnet Market Outlook to 2030, ". . . total magnet rare earth oxide demand [is] forecast[] to increase at a CAGR (compound annual growth rate) of 9.7% . . . the value of global magnet rare earth oxide consumption will rise five-fold by 2030, from US $2.98 billion this year to US $15.65

[5] Source: http://metalpedia.asianmetal.com/metal/rare_earth/application.shtml.

billion at the end of the decade."[6] The highlights go on to forecast supply shortages of the REE neodymium and praseodymium:

> Constrained by a lack of new primary and secondary supply sources from 2022 onward, Adamas Intelligence forecasts that global shortages of neodymium, praseodymium, and didymium[7] oxide (or oxide equivalent) will collectively rise to 16,000 [metric tons] in 2030, an amount equal to roughly three times Lynas Corporations annual output, or three times MP Materials' [Mountain Pass Mine] annual output. . .[8]

The continued increase in global demand necessitates a similar increase in global REE production.

China and Southeastern Asia (China/Southeastern Asia or China/Southeastern Asia region) dominate all parts of the REE market value chain - from extraction and production to final consumption in the manufacturing sector. Even though over the past fifteen years REE mining operations opened elsewhere across the globe, the China/Southeastern Asia region continues to have a virtual monopoly over the global midstream REE separations and concentrations sector of the REE supply chain. The US and the rest of the world (ROW) are dependent upon the region for purity REE products in the form of oxides or metals and for the hundreds of products manufactured in the region that contain REE.

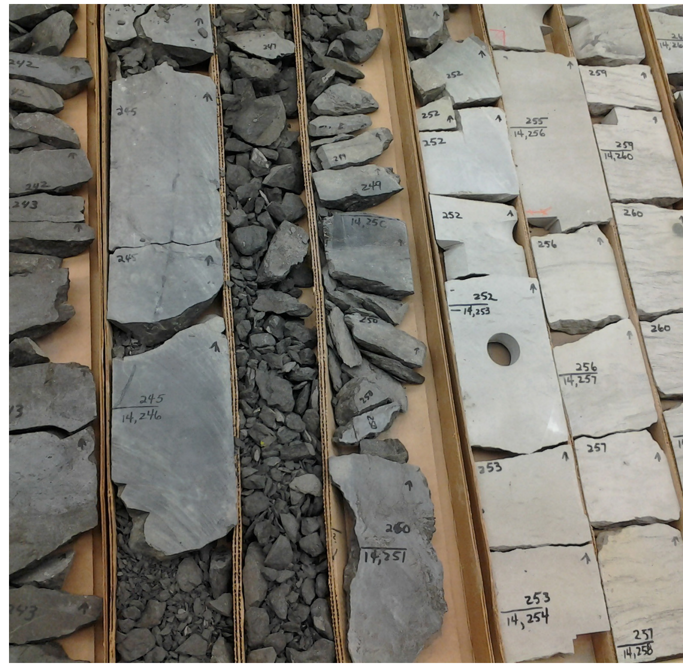
As of 2021, the US has no operational midstream REE purification/concentration capacity. The mined REE concentrate from the US' only operational REE mine, California's Mountain Pass Mine, is shipped to China to be processed into usable REE material. Outside of the Mountain Pass mine, the USGS in its 2017 annual minerals yearbook identifies one other proven US-based REE deposit, the Bear Lodge deposit located in Wyoming, and three REE exploration projects in the US.[9]

The growing threat of the US reliance upon the China/Southeastern Asian region for REE was recognized by the US Department of Defense (DOD) in its FY 2018 Annual Materials Plan for the National Defense Stockpile, when it included more REE acquisitions to increase its inventory of REE.[10] Thus, the federal government is making policy and funding research into the global REE supply chain and the potential for developing REE resources on US soil.

Despite the recent progress in action being taken by federal policy makers, a US-based REE supply chain will struggle to be viable under current market conditions. The current state of the global REE market – in which the China/Southeastern Asia region controls global REE midstream separations and concentrations capacity – inherently diminishes the prospect of a profitable and viable REE supply chain being established in the US. Under current conditions, the vast majority of REE mined output, even if concentrated and separated in the US, would have to be shipped to the China/Southeastern Asian region in

[6] https://www.adamasintel.com/ubs-ndpr-forecasts-miss-mark/.
[7] Not a REE.
[8] Id.
[9] USGS report.
[10] US Department of the Interior and United States Geological Survey (USGS). USGS - 2017 Minerals Yearbook, Rare Earths, p.60.1. https://prd-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2017-raree.pdf.

purity form to be used for manufacturing. Given China's interest in maintaining its control over the REE industry, there is no guarantee that the region would accept US-sourced REE. China's government could also take policy actions to control the price of foreign sourced REE, which could undercut the profitability of a US-based REE supply chain. The reality is that long-term, committed buyers for US-sourced REE must be secured to ensure a robust and long-standing US-based REE industry. A US-based REE supply chain can only be sustainable if fully integrated with a downstream purity REE consumer or set of consumers.



The timing to build, prove, and achieve a fully integrated REE mining, separations, and concentrations operation can span more than a decade. In addition, as this paper demonstrates, because the current structure of the REE market is one geographically concentrated in China and controlled by the Chinese government through quotas, a foreign based new entrant in the REE industry faces structural challenges to operating a successful, long-term business. The critical nature of REE and US reliance on foreign sources are leading to federal interest in securing a domestic REE supply chain. A secure, domestic REE industry will require policy support at all levels of government given the critical nature of the materials to the national security interest of the US and the current market barriers that characterize the REE market today.

Introduction

The University of Wyoming School of Energy Resources (SER) is focused on energy-driven economic development for the state of Wyoming. Given Wyoming's REE deposits and resources, both conventional and unconventional, the global landscape of the REE industry must be fully understood before suggesting actions to build a REE industry in Wyoming. Thus, this paper examines the global landscape of the REE supply chain, REE consumption, and prices to provide an understanding of the unique nature of the REE market and the risks to building a supply chain outside of China/Southeastern Asia. In addition, the increasing interest by the US government in securing a REE supply chain on US soil, an overview of US government policies, and funding for REE projects and research is provided. A second paper in the two part-series focuses on various actions that would help support the establishment of a fully integrated REE supply chain in the state of Wyoming.

Due to the increasing interest in securing a US supply chain for REE, Wyoming, as home to the Bear Lodge Deposit, has an opportunity to explore the potential of making it and the related REE separations and concentrations plant the cornerstone of a fully integrated, operational US REE supply chain.

Wyoming researchers are already undertaking studies of other potential sources of REE, such as coal, its associated by-products, and waste streams. The University of Wyoming Center for Economic Geology Research (CEGR) in the School of Energy Resources has published results on REE concentrations in coal (Bagdonas et al., 2019) and coal byproducts (Bagdonas et al., 2021 in press; Bagdonas and Mclaughlin, 2017; Enriques, et al. 2016; Bagonas et al., 2016); and conducted several studies on REE in geothermal and oil and gas produced water (Quillinan, 2018). SER is leading two projects under the Department of Energy (DOE) funded Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) Initiative for the US Basins. One project is focused on the Powder River Basin and one project is focused on the Greater Green River and Wind River Basins. Additionally, SER collaborates with the National Energy Technology Laboratory (NETL) and industry partners across Wyoming to characterize the occurrence and distribution of REE in coal and coal byproducts. SER is partnered with NETL, Campbell County, Wyoming, Energy Capital Economic Development, and the City of Gillette, Wyoming on a Technology Commercialization Fund project to investigate REE extraction from Power River Basin coal ash. Investigation of REE occurrences in other sources such as sedimentary phosphates and uranium roll-front deposits are ongoing.

The Wyoming State Geological Survey (WSGS) completed two separate comprehensive investigative studies regarding REE occurrences in the State of Wyoming (WSGS, 2013; 2016). These reports contain detailed data and information about REE occurrences in Wyoming and their related measured concentrations.

An understanding of the complexities of the complete REE value chain is critical, including where REE are sourced, uses and applications of REE, and the overall state of the market for REE.

"An understanding of the complexities of the complete REE value chain is critical, including where REE are sourced, uses and applications of REE, and the overall state of the market for REE."

Section I

REE/REM Overview

REE have similar physical and chemical properties and occur coincidentally within rock that host mineral deposits (i.e., REE-containing ores). The relatively low concentrations of REE in their host material and similar chemical qualities of the set of REE make their isolation and extraction complex and costly. Another complicating factor is the fact that radioactive materials are present in varying concentrations in REE deposits, making waste disposal a challenge. For these reasons, limited economic reserves of REE exist across the globe.[11] As will be described in more detail in Section IV, REE are mined and extracted from rock and transformed into usable form through a very complex, multi-stage, chemically intensive separation and concentrations process that yields REE purity products. For purposes of this paper REE purity products can be in the form of individual rare earth metals (REM) or oxides (REO), specific combinations of REM or REO, or "[a] mixture of REE in metallic from, usually admixed with iron, [] called misch metal or mischmetal."[12] The extraction process results in a large quantity of waste and un-used material that must be disposed of or stored.

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[11] REE can also be economically recovered as a by-product when mining other resources, such as zirconium or iron.

[12] Sutherland, W.M. and Cola, E.C., 2016, A comprehensive report on rare earth elements in Wyoming: Wyoming State Geological Survey Report of Investigations No. 71, 137 p. 4 (internal citations omitted).

Fifteen of the seventeen REE are known as the lanthanide series and range in atomic weight number 57 through 71. One lanthanide series element, promethium, does not occur naturally on earth and decays into neodymium-145 through radioactive decay. Scandium and yttrium are not within the lanthanide series but are usually considered REE, due to their similar chemical characteristics to the lanthanide series.

The characteristics and uses of each REE are summarized in Table 1, below. REE are subdivided between Light Rare Earth Elements (LREE) and Heavy Rare Earth Elements (HREE) based upon their atomic number. LREE include the elements lanthanum through samarium (atomic numbers 57 through 62). HREE include the elements europium though lutetium (atomic numbers 63 through 71). HREE are scarcer than LREE, evidenced by lower average concentration in the Earth's crust (Table 1). HREE scarcity combined with the growing demand for their application in emerging technologies, makes HREE more valuable than LREE and consequently HREE command higher prices in the REE market.

Table 1: Summary of Rare Earth Elements

	REE	Symbol	Crustal Concentration (ppm)[1]	Forms[2]	Products Where REE Employed as Critical Component[3]
LREE	Lanthanum	La	32.3	mischmetal, lanthanum oxide, carbonate and other compounds, metal	optical glass, metal alloys, catalysts
	Cerium	Ce	65.7	mischmetal, cerium oxide, carbonate, and other compounds, metal	colored glass, catalytic converters
	Praseodymium	Pr	6.3	mischmetal, praesodymium oxide, carbonate and other compounds, NdFeB magnet alloy	super strong magnets, metal alloys, lasers
	Neodymium	Nd	25.9	mischmetal, neodymium oxide, carbonate and other compounds, metal, neodymium-iron-born (NdFeB) magnet alloy	permanent magnets
	Promethium	Pm	6.3		specialized atomic batteries
	Samarium	Sm	4.7	iodide, oxide, alloy with cobalt	lasers, permanent magnets
HREE	Europium	Eu	0.95	heavy REE mix, oxide, metal	optical fibers, visual displays
	Gadolinium	Gd	2.8	heavy REE mix, oxide, metal	MRI and X-ray
	Terbium	Tb	0.5	heavy REE mix, oxide, metal	fuel cells
	Dysprosium	Dy	2.9	heavy REE mix, oxide, metal	permanent magnets
	Holmium	Ho	0.62	heavy REE mix, oxide, metal	lasers, high strength magnets
	Erbium	Er	2.1	heavy REE mix, oxide, metal	glass coloring, fiber optics
	Thulium	Tm	0.3	heavy REE mix, oxide, metal	lasers, portable X-ray
	Ytterbium	Yb	1.5	heavy REE mix, oxide, metal	stainless seel, lasers
	Lutetium	Lu	0.27	heavy REE mix, oxide, metal	refining
	Scandium	Sc	7	oxide, metal	
	Yttrium	Y	20.7	yttrium oxide, metal, yttrium stabilized zirconia	metal alloys, lasers

[1] https://doi.org/10.1016/0016-7037(95)00038-2.
[2] Nassar, N.T., Alonso, E., and Brainard, J.L., 2020, Investigation of U.S. Foreign Reliance on Critical Minerals—U.S. Geological Survey Technical Input Document in Response to Executive Order No. 13953 Signed September 30, 2020 (Ver. 1.1, December 7, 2020): U.S. Geological Survey Open-File Report 2020–1127, 37 p.,15-24 https://doi.org/10.3133/ofr20201127.
[3] Van Gosen, B.S., Verplanck, P.L., and Emsbo, Poul, 2019, Rare earth element mineral deposits in the United States (ver 1.1, April 15, 2019): U.S. Geological Survey Circular 1454, 16 p. 4, https://doi.org/10.3133/cir1454.

Section II

REE Resources Versus Reserves and Identifying an Economic REE Deposit

Because REE are ubiquitous in the earth's crust, REE are technically recoverable across the globe. However, due to the very low overall crustal concentrations of REE, economic recovery is limited to sources that have relatively high concentrations of REE. "The resource base, resources, and reserves are three related but different concepts as they apply to mineral resources. The resource base for a particular element, or family of elements such as [REE], is the total amount of the element in Earth's crust. Resources are a subset of the resource base: specific occurrences of an element or mineral. . ."[13] Reserves are a subset of resources that ". . . are technically and commercially viable to mine under current market conditions."[14] Reserves differ from a resource in that there has been adequate sampling and testing to prove there is a deposit with a large enough REE concentration to make it economically exploitable.

Economically exploitable REE deposits are uncommon and identified through a thorough sampling process that begins with surface sampling and, if favorable, moves toward more advanced testing, including core sampling. Concentrations of REE are measured in parts per million (ppm) or in terms of Total Rare Earth Oxide (TREO). "The cumulative total abundance of REE in the earth's crust, including scandium and yttrium, ranges from about 20 ppm to 219 ppm . . ."[15]

Conventional REE deposits are hosted in igneous rocks such as carbonatites and peralkaline rocks. Unconventional REE deposits are associated with placer deposits, ion adsorption clays, coal and coal byproducts, and sedimentary phosphate deposits. For simplification purposes, when discussing the REE production process, this paper focuses upon conventional hard rock sources of REE.

As explained in the WSGS 2016 Report on Rare Earth Elements in Wyoming, "REE are often reported in [mt] (1 tonne = 1,000 kg) of Rare Earth Oxide (REO) with all REE lumped together. The designation Total Rare Earth Oxides (TREO) is used in mining and exploration to describe the total REE content in a deposit or sample in an equivalent oxide form, even though their mineral

[13] Eggert, etal., "Rare Earths: Market Disruption, Innovation, and Global Supply Chains," Annual Review of Environment and Resources, August 9, 2016, p 10.1-10.24, p. 10.7.
[14] Id.
[15] Sutherland, W.M. and Cola, E.C., 2016, A comprehensive report on rare earth elements in Wyoming: Wyoming State Geological Survey Report of Investigations No. 71, 137 p. 7 (internal citations omitted).

occurrence may not be in the form of an oxide.”[16] TREO is expressed in percent or can be converted to mt REO. Deposits of REE can range in TREO concentration from <1% to >10% of the total host rock weight, depending upon the deposit type.[17]

Sutherland and Cola, 2016, suggest that “[t]otal REE values greater than 3,000 ppm may be indicative of potential for an economic deposit, depending upon the type of sample.”[18] In general, the higher the REE concentration, the better potential of the resource to be economically exploitable.

Figure 1 below illustrates the process of converting a REE deposit into REE purity products and the related increase in TREO of the material as it undergoes the extraction process.

Figure 1: Material Transformation from Host Rock Deposit to Purity REE Products

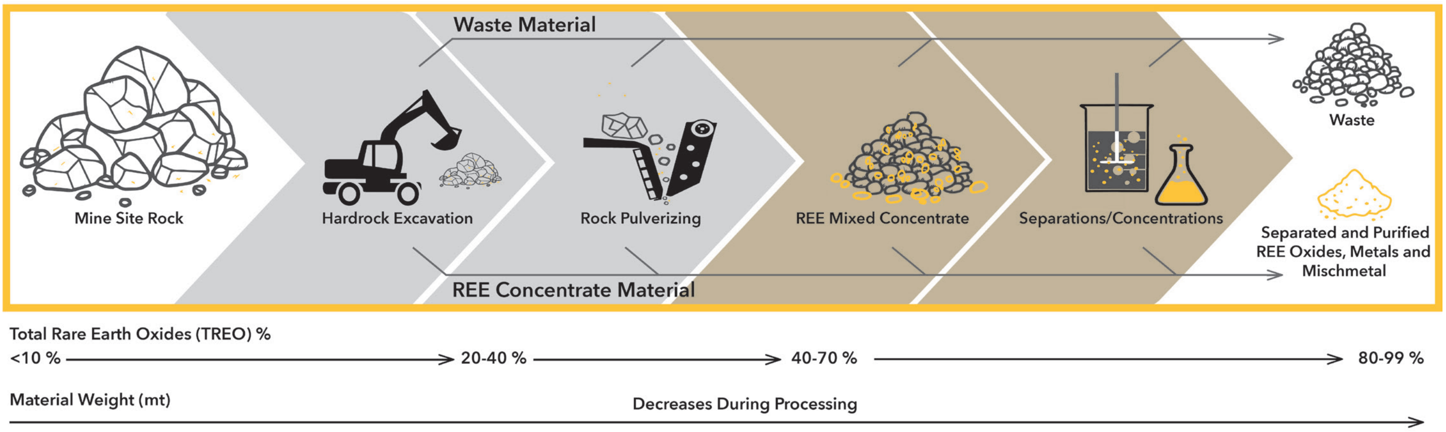

Figure 1 clarifies the difference in weight of the mass of the material in mt and the TREO or mt REO. The large mass of material in terms of weight in mt declines through the process while at the same time the TREO increases. By the end of the process, the remaining material is 90% to 99%+ TREO. Put another way, the actual weight in mt of the final processed and separated streams of REE and the REO weight in mt REO, become nearly equivalent.

Understating the physical changes required to convert a deposit into usable REE and the related change in the TREO of the material is important and unique to REE. An example is provided to help clarify the changes in TREO and weight of the mass of host material as it is processed to extract the REE: Assume that after testing and verification, the TREO of the deposit is proven to be 4%. Further assume that the total deposit weight is estimated to be 100 million mt. One can apply the TREO to the total weight of the deposit to estimate the weight in mt REO of the REE. In this example, the estimated weight of the REE in the deposit would be approximately 4 million mt REO.

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[16] Sutherland, W.M. and Cola, E.C., 2016, A comprehensive report on rare earth elements in Wyoming: Wyoming State Geological Survey Report of Investigations No. 71, 137 p. 4.
[17] Eggert, etal. “Rare Earths: Market Disruption, Innovation, and Global Supply Chains,” Annual Review of Environment and Resources, August 9, 2016, p 10.1-10.24, p. 10.12.
[18] Sutherland, W.M. and Cola, E.C., 2016, A comprehensive report on rare earth elements in Wyoming: Wyoming State Geological Survey Report of Investigations No. 71, 137 p. 7.

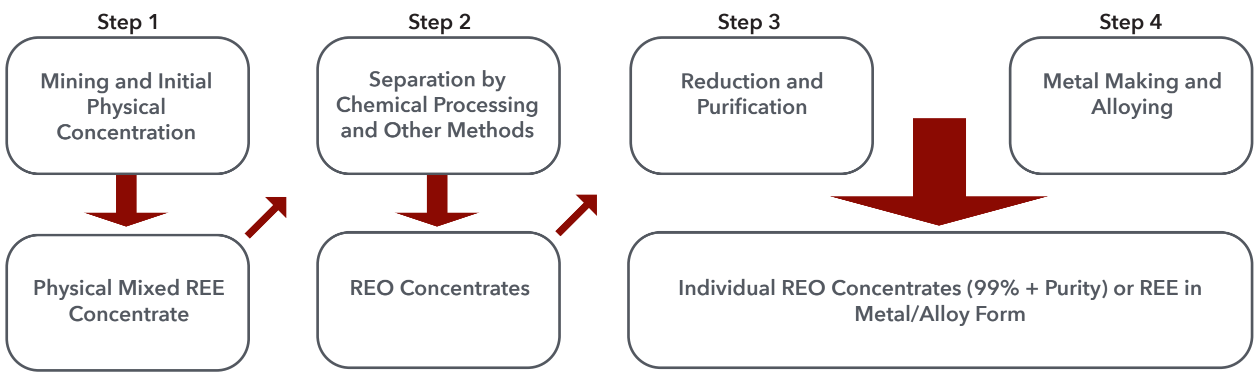
Section III

REE Extraction Process – Mining, Separation, Concentration, and Purification

Once a deposit is identified as economically exploitable, the process of isolating REE begins. The first step is mining or the physical removal of the host rock/mineral from the ground. The mining operations for REE tend to be open pit mines or underground mines where the source rock is drilled and excavated to separate the REE containing ore. The REE containing ore is then stockpiled and must be further processed. The first step of processing also involves an initial physical transformation of the mined material into a smaller mass of material that generates a mixed REE concentrate.

The mining of REE host material is part of the first step in the process of getting REE into usable form. In this paper, the REE extraction process is characterized by four steps as illustrated in Figure 2:

Figure 2: Rare Earth Element Extraction Process



After the rock is mined, it goes through the first step of physical beneficiation –the term used to describe the process where the mined ore is reduced in size to increase its economic value. Other terms often used interchangeably with beneficiation in the literature include: refining, purification, and extraction. In Figure 2, the initial step in beneficiation is termed “initial physical concentration.” This step typically occurs at the mine site. The resulting material after the first step is a large mass of dry, crushed, and powdered concentrate that contains all the occurring REE, i.e., mixed concentrate.

The US Environmental Protection Agency (EPA)’s report, “Rare Earth Elements: A Review of Production, Processing, Recycling, and Associated Environmental Issues,” (EPA, 2012) explains:

> The first step typically includes crushing the ore and separating the REO by flotation, magnetic, or gravimetric separation. This separation process dramatically increases the percentage of REOs in the working material. . . . A tremendous amount of discarded waste rock (tailings) is generated in this process and is typically managed

> onsite or used as backfill material. Chemical changes typically do not occur during the first step, and this process is usually situated near the mine site to reduce transport costs.[19]

Stopping at this point in the process, the remaining mixed physical concentrate weight is significantly less than the weight of the initial mass of host material and the REO content of the physical concentrate, or TREO, is much higher (~20-40%). Next, in Steps 2-4 as shown in Figure 2, this mixed physical concentrate is further processed and converted into separate streams of REE or streams that contain more than one REE. The process involves milling and flotation, leaching and impurity removal, and separation and extraction. The EPA 2012 study continues:

> Subsequent steps in the process aim to change the concentrated mineral into more valuable chemical forms through various thermal and chemical reactions. Typically utilizing hydrometallurgy techniques (e.g., leaching, extraction, precipitation), the mineral concentrates are separated into usable oxides. Further processing by techniques such as metallothermic reduction can refine the oxides or metal mixtures into high-purity REMs.[20]

Moving through Steps 2-4 further reduces the weight of the material to increase the TREO. By Steps 3 and 4, the material remaining is in purity form of mixed and/or separated oxides, mixed and/or high purity metals that are >99% in REO weight. The weight of the final marketed material or REE purity products is essentially equivalent to the REO weight and in the form of REE purity products.

Section IV

REE Market

Like every market, the REE market has a supply side, the production piece of which was described previously, and a demand, or consumption, side. Based upon the information presented thus far, one might consider REE to be a commodity like steel, oil, or coal, but each of those commodities has inherent intrinsic value – the raw material itself is purchased and used or applied in its raw form. REE are distinguished from other true commodities in two key ways: (1) each REE or a specific mixture of REE is a necessary component to either enable a process that results in an end-use product (i.e., REE used as catalysts for oil refining) or in the functional ability of end-use products (i.e., cell phones) with the result that demand for REE is driven by specific end-use product demand and (2) unlike other true commodities characterized by a transparent and active open market exchange consisting of many buyers and sellers, REE are typically bought and sold among a limited set of suppliers and buyers under private contracts.

[19] Rare Earth Elements: A Review of Production, Processing, Recycling, and Associated Environmental Issues, EPA, December 2012. P. 4-1 (internal citations omitted).
[20] Id, emphasis added.

The REE market is not transparent - there is not an active daily or futures market for REE. End-users (i.e., manufacturers of the final product that contains or uses REE) contract directly with downstream REE suppliers under private contracts that are not publicly available. The vast majority of final REE purity product suppliers are located in China and not required to share their proprietary information with any entity outside the Chinese government.

Because a real-time transactional market for REE does not exist and the majority of the market transactions occur in China/Southeastern Asia, detailed and transparent data for REE demand and price are scarce. The data that are available are compiled by private companies and available to customers for a fee. Such companies conduct surveys of a limited number of REE market participants for REE volume and price information, which is aggregated to generate an indicative prices for REE purity products. Because REE contracts tend to be longer in tenor (i.e., months), reported prices tend to be more stable and exhibit limited variance between surveys. Significant market issues that would typically impact real-time market prices, if REE had such a market, are not reflected in regularly published prices.

A. Supply

The supply chain for REE can be broken down into three parts:

Upstream:

The upstream REE production process is limited to the first step of REE production, namely, mining and initial concentration. The REE upstream market can be likened to the oil market's exploration and production sector or to coal mining: identify a resource, prove its potential, contract and complete legal requirements to drill/mine, and drill/mine the resource. The upstream process includes:

- resource identification
- resource testing and evaluation
- permitting and legal citing issues (at the state and/or the federal level)
- environmental application review and studies
- build-out of the mining operation and initial concentration/beneficiation of mixed concentrate
- delivery to the processing plant
- contract for output

Midstream:

The REE midstream segment performs as refineries do in the oil industry, where oil is refined into usable products like gasoline, diesel, and jet fuel. The REE midstream process includes:

- contract for the purchase of mined REE concentrate material
- receipt of REE mixed concentrate
- permitting and legal citing issues
- environmental application review and studies

- build-out and operation of the processing plant to separate, concentrate, and purify REE into oxide form
- contracts for chemicals and necessary inputs to the separation process
- the build out of a smelting, metal making, and/or alloying operation to get REE into REM

Downstream:

Finally, the REE supply chain downstream is reflective of marketing and delivering the final REE purity products to customers. In the oil sector this occurs when refined products like gasoline and diesel are sold to retailers (i.e., gas stations). The REE downstream process includes:

- identification of customers and contract negotiations
- sales of the products including marketing and contracting output
- physical delivery of product(s)
- waste disposal and cost

An important aspect of the supply side of the global REE industry is the geographical concentration of the REE supply chain in the China/Southeastern Asia region.

"Despite the increase in countries outside of China establishing REE mining operations, the midstream and downstream parts of REE supply chain are nearly completely controlled by China."

According to USGS data, China's dominance over global mined REE production declined to 58% of the global total in 2020 from its peak of 93% in 2009. Despite the increase in countries outside of China establishing REE mining operations, the midstream and downstream parts of REE supply chain are nearly completely controlled by China. The REE mixed concentrate output from the mines established outside of China, is mostly shipped and sold to midstream processors in China. In 2019 Adamas Intelligence estimated that at least 85% of global rare earth processing capacity was located in China.[21]

China's dominance in the midstream and downstream aspects of REE production is further evidenced by the fact that the entirety of US output from the Mountain Pass Mine is exported to China for processing. With China's near monopoly in the midstream separation/concentration sector, China shifted to a net importer of REE raw material in 2018. Thus, if nothing changes, China could continue to control REE global supplies even if the US and other countries begin producing raw REE materials – highlighting that a broader REE strategy is needed to diversify the supply chain.

i. Global REE Reserves Estimates

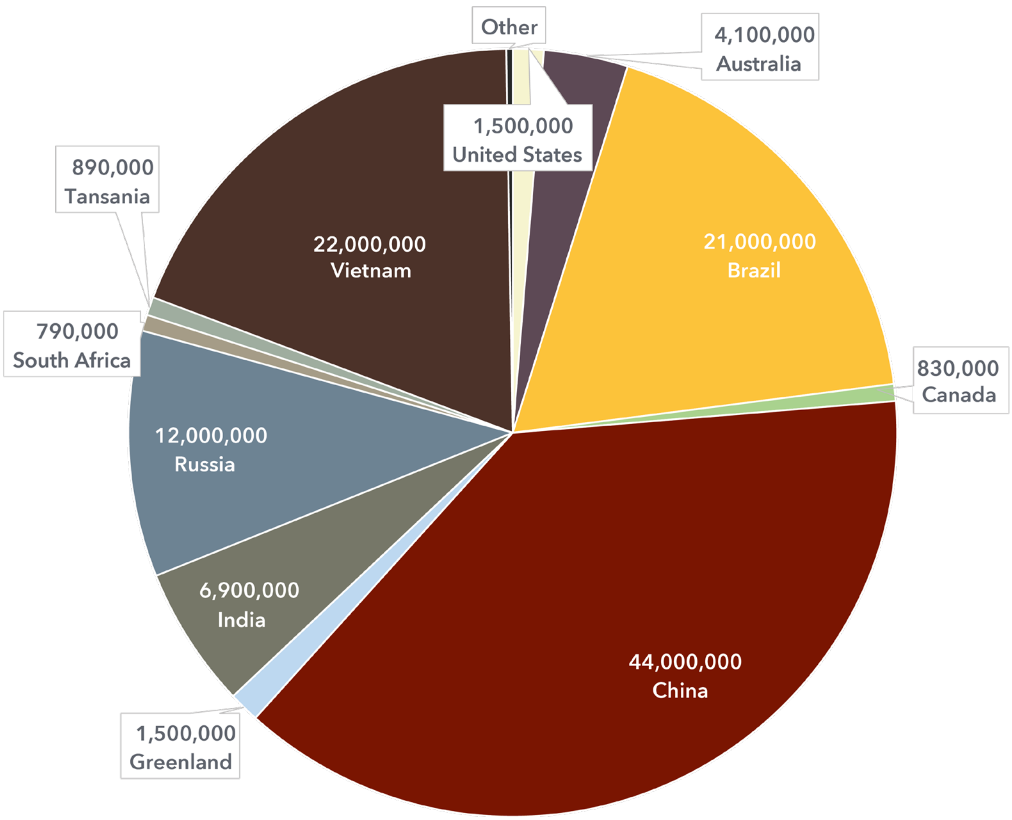
The USGS publishes annual reports on global REE reserves and production reported as mt REO. For global reserves, the USGS estimates do not include reserve estimates for some countries that are known to produce meaningful amounts of REE such as, Burma, Burundi, Madagascar, Myanmar, and Thailand. Therefore, when considering USGS data, one should be mindful of the fact that the USGS total global REE reserves estimate is lower than the actual global reserve level.

The USGS in its Mineral Commodities summaries for REE published in January 2021 estimates that total global REE reserves in 2020 were 120 million mt REO. The estimated reserves by country in the report are shown in Graph 1.

[21] https://www.reuters.com/article/china-rareearths/update-2-china-raises-annual-rare-earth-output-quotas-to-record-high-idUSL3N27O341.

The USGS data show that while China currently has the most proven reserves, other countries like Vietnam and Brazil also possess significant reserves. The relative size of each country's reserve amount, however, does not necessarily correspond to its production level. For example, Vietnam and Brazil each produced only 1,000 mt REO of mined REE, or 2,000 mt REO in total, in 2020 which represented only 0.8% of global production; yet together the countries represent 37% of the USGS estimated global REE reserves. The US represents only 1.3% of global REE reserves, but its REE mined production in 2020 was estimated to be 15.6% of total global mined production. The global reserve estimates illustrate China's dominant position and the significant resource potential of other countries.

Graph 1: USGS Estimated Global REE Reserves by Country



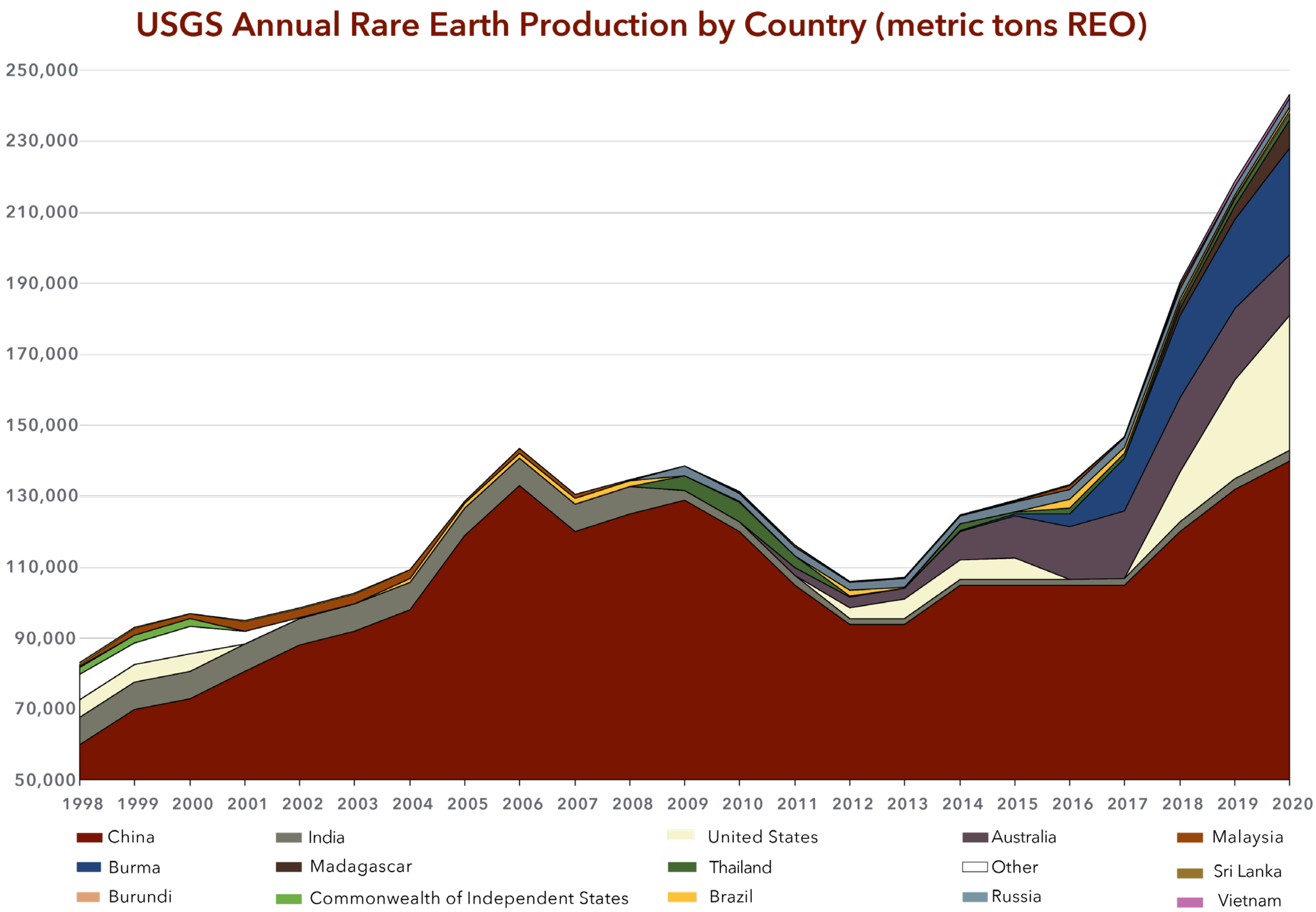
ii. Global REE Production

REE production by country across the globe has shifted over time and until the 1990s, when China began ramping up its REE industry, the US was the dominant global producer. China's REE production increased significantly in total and as a portion of global production, as demonstrated by Graph 2, and described below:

> In the late 1980s, China began mining their in-country REE deposits, processing their ore and extracting and separating the individual REEs for use in products, which they also manufactured. China quickly gained control of global REE production, providing 95 percent of the global market of processed REE by 2011. Between 2011 and 2017, China produced approximately 84 percent of the world's REEs, followed by Australia with about 8 percent of production. Within this period, the United States only produced REEs between 2012 and 2015, entirely from the Mountain Pass mine, which contributed only about 4 percent of the world REE supply. [22]

[22] Van Gosen, B.S., Verplanck, P.L., and Emsbo, Poul, 2019, Rare earth element mineral deposits in the United States (ver 1.1, April 15, 2019): US Geological Survey Circular 1454, 16 p.4 (internal citations omitted). https://doi.org/10.3133/cir1454.

Graph 2: USGS 2020 Estimated Global Annual Rare Earth Production



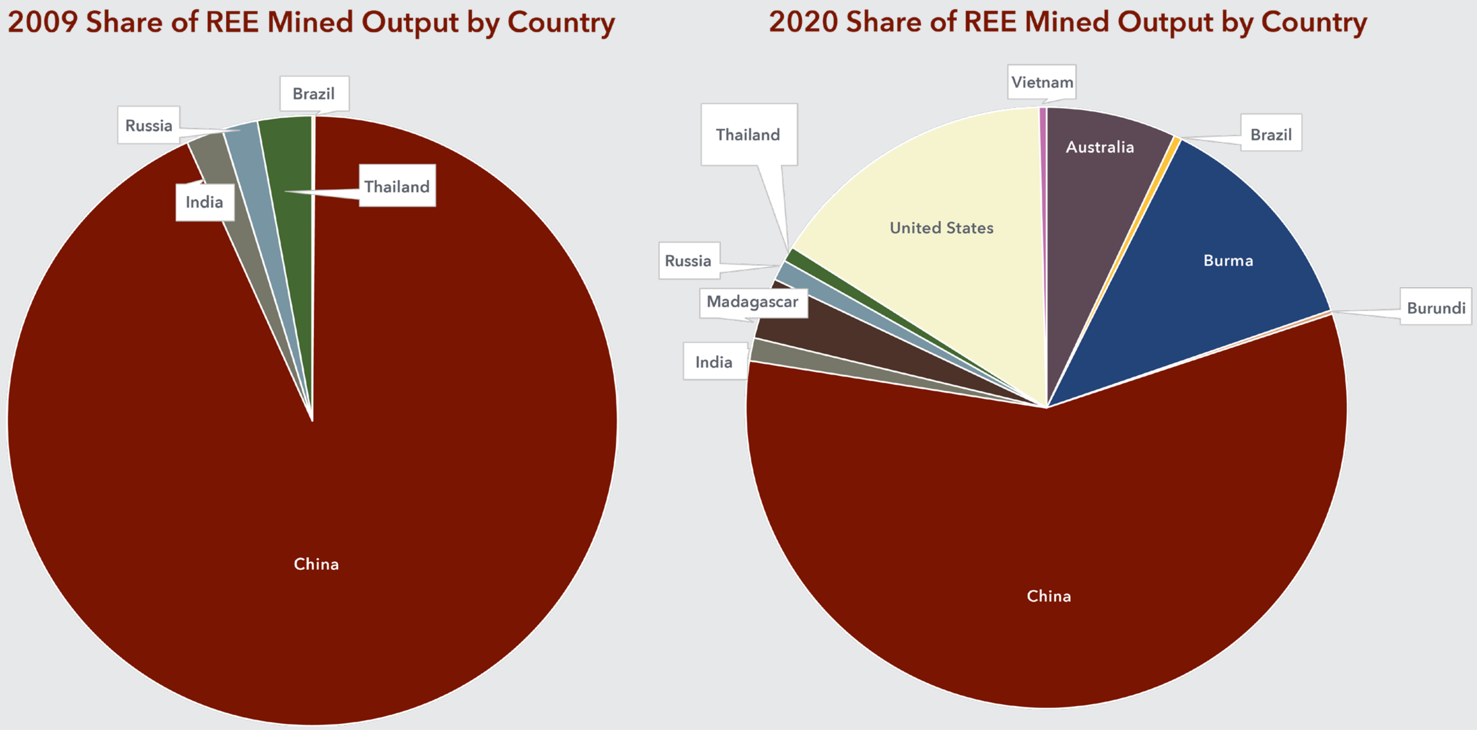
In 2000, total global REE production was estimated by the USGS to be 90,900 mt REO with the top three producers being China at 73,000 mt REO; the US with 5,000 mt REO; and India at 2,700 mt REO. The US produced zero REE from 2001 through 2011 and again in 2016 and 2017. Since 2010/2011, other countries began establishing and ramping up REE mining, particularly in Burma and Australia. With its latest report, the USGS estimates that in 2020 total global production increased to 240,000 mt REO,[23] with China remaining the dominant supplier producing 140,000 mt REO and the US in second place with 38,000 mt REO. China and US production combined as a percent of total global production declined from 92.6% in 2000 to 74.2% in 2020.

While China dominated the upstream sector of the REE market for quite some time, its near monopoly has declined with REE mining operations ramping up in other countries. Employing USGS data, in 2009, four countries produced mined REE with China's production representing 93% of the total, and the remaining 7% produced by Thailand, India, and Russia. By 2020, the mined production profile shifted, with China comprising 58% of the total and four other countries, that include the United States, Australia, Burma and Madagascar, producing 38%; the remaining 4% of global production occurred in

[23] The USGS estimate does not include know production from places like Myanmar. It also does not include REE from other countries that are exported to China.

Russia, Brazil, India, Thailand, Vietnam, and Burundi. The charts below demonstrate the significant shift in the concentration of REE production by country.

Graph 3: 2009 and 2020 Global Mined REE



a. USGS REE Global Production Data, United Nations (UN) REE Trade Data, and Revised Estimate of REE Production

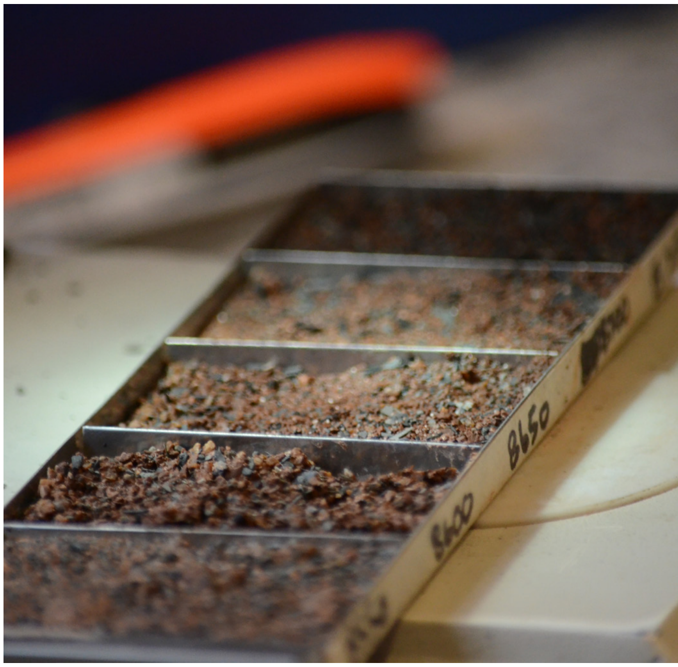
The USGS data sets do not include several currently known sources of REE production. Examples include, (1) REE concentrate production from other Asian countries, like Japan, that continue to produce REE mixed concentrate and export it for further concentration to China; (2) REE materials produced in Europe; and (3) Myanmar HREE production. This means that the USGS data are missing significant sources and related amounts of global REE production and the USGS global production estimate is lower than actual global production.

Given that the USGS global REE production data exclude known sources of REE production, this paper endeavors to account for some of the known streams of REE production to generate a more complete global production estimate for REE.

The UN, through its Comtrade database,[24] publishes comprehensive statistics and data regarding international trade between UN member countries across the globe. Among many other goods, it documents actual trade information by country for three categories of REE with dollar value and total weight in kg. The data include REE data for every UN member country across the globe, including countries that the USGS data exclude.

[24] https://comtrade.un.org/.

Theoretically, one should be able to apply the import and export data from the UN to estimate production levels of countries with known REE production that are excluded from the USGS data.



The UN data also have limitations and compatibility conflicts with the USGS data. First, the UN data exclude non-UN member countries. For instance, the UN data show that Benin imported 55,000 mt of REE, but the source country for the REE is Turkmenistan,[25] which is not a member country of the UN, and therefore its exports are not included in the UN data. Another example of a known problem with the UN data is that in 2020, it is estimated that exports to China from Myanmar totaled 35,500 mt in gross weight,[26] but UN data show Myanmar exports to be zero in its data for 2019.

Challenges arise when comparing the production weights reported by the USGS in its reports and the weight of REE imports and exports tracked in the UN Comtrade data sets. USGS production data are reported in mt REO, but UN Comtrade data are reported in kg (a conversion from kg to mt is necessary). The difference in mt REO and mt make a direct comparison between the data sets problematic.

The UN Comtrade data includes many different streams of REE – some are mixed concentrates whose mass weight is significantly larger than its mt REO and others are REE purity products whose mass weight is much closer to its mt REO weight. Because there is no differentiation between the various streams of REE, calculating TREO conversion factors is problematic.

Given the objective of generating a revised, more comprehensive estimate of global REE production, publicly available data must be employed to develop estimates of the production that USGS data is known to exclude, but that UN data may include.

Data exist for specific countries where publicly traded companies own and operate REE businesses. Data from the companies include mined tonnage, REO percentage of the mined concentrate, and other relevant production data. In addition, there are instances of production estimates for specific countries from private analytics companies, as noted for Myanmar.

In Section V. A. ii., above, USGS published estimated 2020 data were presented, but current UN import/export data are available only through 2019. Consequently, 2019 data from the USGS and the UN form the basis for the re-estimation of global REE production.

Table 2, below, compares 2019 USGS REE production data by country in mt REO to the UN Comtrade data for total REE imports and exports.

[25] https://oec.world/en/profile/bilateral-country/ben/partner/tkm.

[26] https://roskill.com/news/rare-earths-myanmar-coup-detat-creates-more-uncertainty-for-heavy-rare-earth-supply/.

Table 2: Comparison of USGS REE Production and UN Reported REE Imports/Exports

2019			
	USGS	UN COMTRADE	
Country	Production	Exports	Imports
	REO	*mt*	*mt*
Australia	**20,000**	29	282
Brazil	**710**	0.24	2,101
Burma	**25,000**		
Burundi	**200**		
China	**132,000**	46,331	41,110
India	**2,900**	2,230	1,848
Madagascar	**4,000**	-	160
Malaysia	**-**	42,765	52,877
Sri Lanka	**-**	251	3
Russia	**2,700**	6,217	1,329
Thailand	**1,900**	1,476	3,191
USA	**28,000**	47,015	21,486
Vietnam	**1,300**		
Total	**218,710**	**146,313**	**124,386**
Other Import/Export			
Europe		34,234	119,955
Myanmar		-	0.02
Japan		4,774	27,135
Other Asia		5,825	11,074
		44,833	158,164
Rest of World		1,387	58,262
Total Comtrade Imports and Exports		**192,533**	**340,812**

Table 2 shows total global REE production from the USGS of 218,710 mt REO for 2019 (lower than the 240,000 mt REO of production estimated by the USGS for 2020). The UN data, weight in mt, show a total of ~193,000 mt of REE exports and ~341,000 mt of REE imports.

Given the data issues noted previously, arriving at a revised estimate of global REE production requires some known and measurable adjustments to the data.

For the US, data are available for produced concentrate in mt REO from the USGS, total exports of REE in mt, and the percent REO of the concentrate from the Mountain Pass Mine. As can be seen in Table 2, the estimated production in 2019 for the US from the USGS is 28,000 mt REO. Because the only operational mine in the US is Mountain Pass, it is known that the 28,000 mt REO represents the REE concentrate weight after initial concentration at the Mountain Pass Mine. The UN data in Table 2 show total US exports of 47,015 mt which implies that the produced REE concentrate from the Mountain Pass mine is about 60% TREO (28,000 / 47,015 = 60%).

The calculated REO concentration matches up exactly with the publicly reported concentration of the Mountain Pass Mine's in MP Materials' (the owner and operator of Mountain Pass) 2020 Securities and Exchange Commission (SEC) 10K report. The report shows total mt REO production in 2019 of 27,620 (essentially the same as the USGS), and notes the following:

> The rare earth concentrate we currently produce is a processed, concentrated form of our mined rare earth-bearing ores. While our unit of production and sale is a [mt] of embedded REO, the actual weight of our rare earth concentrate is significantly greater, as the concentrate also contains non-REO minerals and water. We target REO content of greater than 60% per dry [mt] of concentrate (referred to as "REO grade").[27]

MP Materials contracts with Chinese based Shenghe for the purchase of nearly 100% of its mixed concentrate which is shipped to China for further processing. This demonstrates the US supply chain's dependence on China's REE midstream processing capacity.

Malaysia and Australia data from the UN differ from the USGS data for 2019. The USGS data show that Australia's production was 20,000 mt REO and Malaysia's was zero. In Australia, essentially all mined REE concentrate comes from the Mt. Weld Mine owned by Lynas Rare Earths Limited (Lynas).[28] According to Lynas, the Mt. Weld Mine includes a concentrator that completes the initial concentration process of the mined ore.[29] The plant is designed to process 240,000 mt/year into up to 66,000 mt/year of concentrate containing 26,500 mt of REO. This implies that the percentage of REO in the initial concentrate is ~40% TREO. The concentrate is shipped to the REE separations facility Lynas owns in Malaysia to be processed. The separations facility can produce 22,000 mt REO of separated purity REO products annually.[30] Given the publicly available information from Lynas, it appears that the USGS production data for Australia are the mt REO that exit the Malaysian separations facility.

UN data show imports of 52,877 mt to Malaysia in 2019, which is the mined concentrate coming from Australia. UN data show exports of 42,765 mt out of Malaysia, which is the gross weight of the purified separated REO concentrate.

The USGS production data do not include Myanmar, Europe, and other countries in the Asian region outside of those countries that export REE concentrate and in some instances REE purity products. For these countries, an assumed TREO of the import/export weight of 60% is applied.

The USGS data also exclude illegal production in China. In 2016, the USGS estimated that total global REO production was 133,000 mt REO. Estimates for 2016[31] indicate that illegal production was an additional ~25% of the global total, or an

[27] MP Materials Corp. US SEC Form 10-K, Annual Report for the fiscal year ended December 31, 2020, p. 47.
[28] https://lynasrareearths.com/.
[29] https://lynasrareearths.com/about-us/locations/mt-weld-western-australia/.
[30] https://lynasrareearths.com/about-us/locations/kuantan-malaysia/.
[31] "Roskill Charts Trends in Rare Earth Industry." Professional Services Close-Up 10 Nov. 2016. Business Insights: Essentials. Web. 14 Sept. 2021.

additional 33,250 mt REO of production. Given the fact that the Chinese government has cracked down on illegal mining operations while at the same time its total output has increased, the amount of estimated illegal production from 2016 is applied and included in the total production estimate.

Table 3 presents the calculation of the re-estimated REE global production for 2019:

Table 3: 2019 Estimated REE Global Production

2019 ESTIMATED GLOBAL REO PRODUCTION - USGS + 60% REO OF OTHER PRODUCTION	
USGS REO mt	218,700
Myanmar 2020 est REO mt	18,900
Europe Exports REO mt	20,500
Other Asia Exports REO mt	6,400
Total	264,500
Estimated Illegal Production REO mt	33,300
Estimated Global Production REO mt	297,800
Estimated actual weight mt	474,100

The increased global REE production estimate is ~36% larger than the USGS estimate. While this estimate and approach employed for deriving REO production omitted by the USGS is admittedly simplistic and incomplete, it nonetheless demonstrates the overarching and key point – the USGS production data are too low and ***global REO equivalent mined production in 2019 was likely at least ~298,000 mt REO.***[32] Assuming that global average TREO is ~60%, total global production of REE in 2019 is estimated at ***~474,000 mt in actual weight***.

If the estimated 2020 USGS production of 240,000 mt REO is re-estimated using the same 36% derived estimate of missing global production, it yields total REE production of ~326,000 mt REO.

[32] This does not account other production sources that could not be specifically identified.

iii. China's Dominance Over the REE Global Market

The paper thus far has referenced the China/Southeastern Asia region's dominance and virtual monopoly control over the full REE value chain, on both the supply side and the demand side. The region's dominance in the global REE industry expanded over time to its current monopolistic position, driven primarily by China's increased government control over its REE industry.

Government regulation over REE in China began in 1975 with the inception of the National Rare Earth Development and Application Leading Group. REE production in China was relatively small until the government targeted increasing exports of REE in 1985 by implementing an export tax reimbursement payment. This led to a significant increase in REE production, and by 1990 production had doubled to 16,500 mt REO.[33]

A combination of events in other countries in 1989 and 1990 contributed to further growth in China's REE industry. In France, a REE processing plant was denied extension of its radioactive waste disposal permit.[34] This caused the company to move its facility to China. During the same period, Japan was shuttering its REE processing facilities and moving them to China. At this juncture, the REE industry in China was growing and profitable. However, the ramp up of REE production operations, and in particular illegal operations in China,[35] caused supply to increase rapidly and in turn impact prices negatively. Due to the growth in the REE industry and the impact of illegal production, the Chinese government became more active in its regulation of the REE industry.

In 1990, the Chinese government declared REE a strategic resource for the country and consequently determined it be a protected resource.[36]

> . . . China started to restrict foreign investment in the early 1990s, especially in the upstream sector. All foreign investment in the [rare-earth] industry had to be approved by the [Rare Earth] office. Foreign investors had restricted access to RE[E] exploration, mining, beneficiation, smelting, and separation. Foreign investment could not be involved in any projects that damaged the environment and natural resources (RE office et al. 1990; SPC and MFTEC 1995a, 1995b, 1997).[37]

Then in 1991, the Chinese government took over regulation of all steps of production of REE from its ionic clay resources. State-owned mining companies (those owned and operated by the government) took priority for mining, while private enterprises were

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[33] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 130.

[34] Ibid.

[35] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 127.

[36] Tse, Pui-Kwan, 2011, China's rare-earth industry: US Geological Survey Open-File Report 2011–1042, 11 p. 5, available only online.

[37] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 131.

prohibited from participating. In addition, only state-owned mining companies could run REE separation and smelting operations. The government executed all trade associated with the REE from ionic clay. From 1991 to 1998 REE production increased from 16,500 mt REO to 65,000 mt REO.[38]

In 1999 China began employing a REE export quota scheme that encouraged the production of oxides and metals (the midstream and downstream supply side sector) and favored state-owned firms. "Starting in 2002, only joint-venture RE[E] smelting and separation enterprises were allowed but no wholly foreign-owned enterprises in the RE[E] mining sector."[39] The Chinese government issued

> . . . [t]he document, "Notice on Rectification and Standardization of Development Order of Mineral Resources," [which] was a general and vital administrative notice for reorganization of the entire mineral industry (State Council 2005). . . .The document specifically stated the requirements for the RE[E] industry that the Ministry of Land and Resources (MLR) together with other ministries, such as [National Development and Reform Commission of China] NDRC, the Ministry of Commerce (MOFCOM), and [Ministry of Industry and Information Technology] MIIT,[40] were responsible for the rectification of mining, beneficiation, separation processing, and trading of RE[E] products. Further, according to this document, MLR started to set RE[E] production quotas. . .[41]

From 2005 to 2010, while China's REE production continued to increase, its exports decreased. The export-tax reimbursement policy that helped support the development of China's REE industry was cancelled in 2005. In 2006, a REE concentrate production quota was instituted that was applied directly to producers. To further restrict exports, in 2007, China started to levy export taxes for all REE ores and downstream REE oxides and metals. In 2010, ". . . China imposed an export tax on the end-use-product NdFeB alloy that was not used for permanent magnets."[42]

> The stricter export taxes were aimed at incentivizing the downstream sector, restricting RE[E] production, and protecting the nonrenewable resource. However, the taxes imposed on legal firms created even higher profit margins for illegal firms. The export tax discouraged legal exports of less processed RE[E] and contributed to the transformation of the structure of the Chinese RE[E] industry: while the total quantity of exports decreased after 2005, the portion of further processed RE[E] products increased.[43]

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[38] Ibid.

[39] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 132.

[40] Until 2008, China's Ministry of Land and Resources (MLR) was responsible for setting production plans and quotas for REE. In 2008 the Rare Earth Office was moved under the Ministry of Industry and Information Technology (MIIT) and the MIIT also issued production quotas. With both offices issuing differing quotas there was confusion among the REE production sector. In 2010, both offices began to establish identical quotas.

[41] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 132.

[42] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 133.

[43] Id. (internal citations omitted).

The US and other countries challenged China's export restrictions at the WTO arguing that its restrictions did not comport with the *Protocol on the Accession of the People's Republic of China*, the document by which China was admitted to the WTO. China lost the dispute and subsequently canceled its export quotas and taxes in 2015.

China continues to establish production quotas. China's REE mining output quotas have changed over time. Since 2010, when the annual quota was 89,200 mt/year, the mining production quotas consistently increased to 140,000 mt/year in 2020, and most recently the quota was increased to 84,000 mt for the first half of 2021 (annualized, this would be 168,000 mt).[44] Despite the government establishing production quotas, the issue of illegal mining in China cannot be ignored.

It is widely acknowledged that there continues to be illegal REE production coming from China and therefore, when considering REE data, it is important to remember that the official mining output data from China and reported data from other sources do not include or contemplate the black-market production source. Quantifying the illegal production of REE in China is fraught with difficulty. Some studies estimate:

> . . .that the illegal production was about 30% of total production between 2005 and 2012 and dropped below 20% after 2014. This estimation supports the claim that the China's RE[E] regulation was effective and illegal activities were falling. [Other studies] largely diverge[] from this estimation. . . .[and indicate] that the illegal-sector production was equivalent to about 23% of total production before 2013, but increased drastically above 50% after 2017—implying that China's policies failed to curtail the illegal production at all. Nevertheless, all the estimates support the theory that illegal upstream and midstream operators provided substantial cheap primary inputs to the downstream sector.[45]

In 2016, it was estimated that illegal production represented 25-30% of global rare earth supply.[46] More recently, in 2020, Argus Metals forecasted that China's illegal production would decline from 60,000 mt/year in 2017 to 8,000 mt/year by 2021.[47] The decline in illegal production is attributed to the government's increased scrutiny upon illegal operations and its regular inspections to identify and close those operations.

China's increased government control over its REE supply chain, combined with other countries increased regulation over their REE midstream operations, led to the current state of the global REE supply chain. The supply side of the global REE market is characterized by an upstream mining market that, while arguably more diversified in terms of country source of mined REE,

[44] China hikes half-year rare earth output quotas to record level | Reuters https://www.reuters.com/article/us-china-rareearth-idUSKBN2AJ18O.

[45] Shen, Yuzhou et al., China's public policies toward rare earths, 1975–2018, Mineral Economics (2020) 33: 127-151, p. 134. (internal citations omitted).

[46] "Roskill Charts Trends in Rare Earth Industry." Professional Services Close-Up 10 Nov. 2016. Business Insights: Essentials. Web. 14 Sept. 2021.

[47] https://www.argusmedia.com/en/news/2054597-chinas-rare-earth-consolidation-to-cut-supplies.

continues to be captive to a midstream and downstream REE industry geographically concentrated in China that is de facto controlled by the Chinese government. The fact is that midstream and downstream REE processing are arguably the most important functions of global REE supply chain; without it, REE would not be usable. This bottleneck will remain, absent new capacity being built in other countries. By virtue of China's monopolistic control of the global REE midstream and downstream fleet, new entrants into the space outside of China are subject to monopoly market behavior which can easily lead to the new entrant's premature financial and operational demise. For a midstream and downstream industry outside of China to be successful, foreign governments must institute policies that aid not only in the build out of the requisite infrastructure but that support the long-term viability of the industry.

"By virtue of China's monopolistic control of the global REE midstream and downstream fleet, new entrants into the space outside of China are subject to monopoly market behavior which can easily lead to the new entrant's premature financial and operational demise."

Another major hurdle to establishing a new midstream and downstream REE operation outside of China/Southeast Asia is, under current market conditions, the REE purity product output would in all likelihood have to be sold to a manufacturer located in the China/Southeastern Asia region given the region's control over the global manufacturing capacity that employ REE.

As will be demonstrated subsequently, the China/Southeastern Asia region consumes over 70% of global REE production and China alone controls over 90% of the globe's permanent magnet manufacturing capacity, the largest sector of future growth for consumed REE. The demand side of the REE market is like the supply side in its geographic concentration in the China/Southeastern Asia region.

B. Demand

An important defining characteristic of REE is that unlike other true commodities – such as, coal, gold, and oil, REE are not end-use products in and of themselves. REE are an essential part for the operational ability and function of a host of end-use products. Two of the most important uses of REE are as catalysts in many chemical processes and their widespread and growing application in magnetics.

Because REE are a necessary component of consumer end-use products, those markets and their related growth or contraction drive the global demand for REE. Historically, REE were used in lighting applications. With the industrialization of the global economy from the 1900's to the twenty-first century, applications for REE experienced significant growth. "The principal applications in 2000 were in automotive catalytic converters; glass polishing and ceramics; permanent magnets; petroleum refining catalysts; metallurgical additives and alloys, including rechargeable batteries; and phosphors for color monitors, televisions, and energy-efficient fluorescent lighting."[48] The relatively inexpensive cost of manufacturing those items in China and other Southeastern Asian countries, combined with the region's dominance over the REE supply chain, have made the region dominant in the manufacturing capacity for the end-use products that require REE.

Since 2000, with the growth in new end-use technologies in the medical, automotive, and defense industries, combined with an increase in the application of permanent magnets, REE consumption has expanded significantly.

[48] USGS Minerals Yearbook – 2000, Rare Earths Section, p. 62.1.

Permanent magnets and other magnets are used in almost every electronic device and every car. The medical industry relies upon magnets for advanced imaging machinery and pacemakers. The renewable power industry relies heavily upon permanent magnets, with every wind turbine and generator requiring one. Electric vehicle motors also require permanent magnets. Permanent magnets use a combination of the REE Nd and Pr that are alloyed together. Other magnets also use Nd but are combined with iron (Fe) and/or boron (B). Permanent magnet demand is driving REE consumption growth and will continue to so in the immediate future.

China is home to the globe's permanent magnet manufacturing industry. A Global Rare Earth Permanent Magnet Industry Report was published in 2018. Some of the important takeaways from the study follow:

> [The] [g]lobal NdFeB permanent magnet market has grown by leaps and bounds in recent years with the output for 2017 exceeding 170kt, a 78.5% upsurge over 2010, including more than 60kt of high-performance NdFeB, soaring 135.1% from 2010, well above the average growth rate of the industry. Globally, only TDK, Hitachi Metals, Shin-Etsu Chemical and VAC are capable of producing high-performance NdFeB permanent magnet, seizing almost 50% of the world market.

China has been the world's largest producer of rare earth permanent magnets by virtue of its rare earth resource superiority. More than 150kt of NdFeB permanent magnets or about 90% of the global total was produced in China in 2017. Despite the country's massive production capacity, most of Chinese NdFeB enterprises still focus on mid and low-end products and have not yet been strong in high-end products.[49]

China's dominance in the permanent magnet industry has increased and a news report published in 2019 noted, "China is the world's largest both producer and exporter of rare earth permanent magnets. In 2018, it occupied 90.5% of the global total output and exported roughly 39kt worth $1.87 billion, higher volume and value than those in the previous year."[50]

In the US alone, by 2030 many of the various governmental environmental policy mandates - renewable power production quotas, CO_2 emission reduction targets, and the banning of the sale of gasoline and diesel-fueled vehicles - will be in full effect. Achieving these various environmental mandates will require a surge in the supply of permanent magnets. REE consumption, then, and in particular for the REE Nd and Pr, is poised to continue to increase going forward in the permanent magnet manufacturing industry.

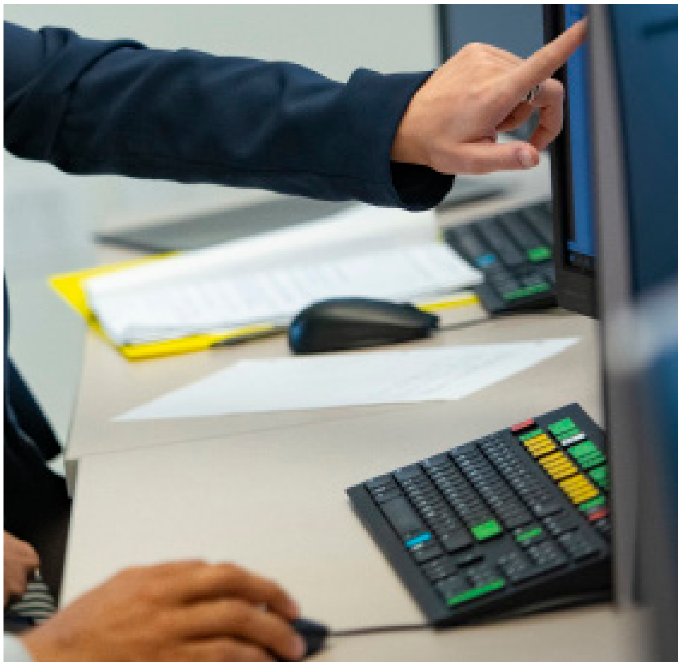
[49] https://www.prnewswire.com/news-releases/global-rare-earth-permanent-magnet-market-2018-2021-with-focus-on-the-chinese-industry-featuring-5-global-players--22-chinese-companies-300660906.html.
[50] https://www.globenewswire.com/news-release/2019/03/29/1788460/28124/en/Global-and-China-Rare-Earth-Permanent-Magnet-Industry-Report-2018-2023-Featuring-5-Foreign-and-25-Chinese-Manufacturers.html.

i. Global Consumption of REE

Ideally there would be comprehensive data available regarding individual separated REE product consumption. Unfortunately, those data do not exist and specific consumption information for each REE is not readily available.

For this reason, quantifying total global demand (or consumption) for individual REE compounds is nearly impossible. There are data available, however, that can be processed, analyzed, and compared to develop a broad understanding of the size and global make-up of the demand side of the REE market. For purposes of the analysis conducted to estimate global REE consumption in this paper, China and countries in the Southeastern Asian region area are combined into one region. This is accomplished due to the region's near complete dominance over the midstream and downstream sectors of the REE supply chain in addition to its control over the globe's consumption side manufacturing capacity.

If one generally considers a market with international trade, Country A's consumption should equal its own production less exports plus imports: C = P – X + I. The same formula applies to the globe. One would logically expect that for the production piece, USGS production data could be used. However, as discussed in prior sections, there are known omissions in the USGS data, and it underestimates actual total global REE production. Therefore, the re-estimated 2019 total global production discussed in Section V. A. ii. a. will be used in actual weight mt combined with the UN import/export weight data to estimate REE consumption.



Using the UN import/export data is challenging as it does not differentiate between the streams of REE that are mixed concentrates and those that are purity products. To clarify, the data provided by the UN are reported in terms of total imports and total exports in weight by country. It is known that certain streams are mixed concentrate – like US exports; and some streams are purity product – like US imports. Put another way, for the China/Southeastern Asian region, the imports to the region from countries like the US, are known to be mixed concentrates. Imports to countries like the US, which are known to come from the China/Southeastern Asian region, are purity REE products. The weight of the mixed concentrate will be larger than the weight of the purity products, but the TREO of the mixed concentrate is much lower than that of the purity products. Other than the few known streams, like US exports and imports, there is no method to apply to the remaining streams of imports and exports to distinguish between purity products and mixed concentrates.

Table 4, below, employs the production estimates from Section V. A. ii. a. and UN Comtrade import/export data by country to generate consumption estimates.

Table 4: Estimated Global REE Consumption in Actual Weight

	(A)	(B)	(C)	(D)		(E)
	ESTIMATED PRODUCTION		EXPORTS	IMPORTS		IMPLIED CONSUMPTION
	mt REO	*actual weight mt*	*actual weight mt*	*actual weight mt*		*actual weight mt*
China/Southeastern Asia (Includes Myanmar)	193,710	312,200	58,400	135,400	i	401,300
Europe	20,540	34,200	34,200	120,000		53,000
USA	28,000	47,000	47,000	21,500	ii	21,500
Australia	20,000	52,900	52,900	300		300
Rest of World	35,550	27,800	33	63,600		91,400
Total	297,800	474,100	192,533	340,800		567,500

i - includes Malyasia and estimated illegal production; consumption estimate assumes Japan, Thailand, and Other Asia exports are consumed within the region.
ii - excludes Estonia imports and exports due to double counting inherent in Europe export/import data.

The China/Southeastern region produces ~312,000 mt (not including Australian production or Myanmar) and imports ~135,000 mt (includes Malaysia). It is reasonably assumed that the REE production in the region stays in the region and the imports also stay in the region, whether mixed concentrates or purity REE. The China/Southeastern region in the table above shows ~401,000 mt/year of consumption. Because all the region's own production and imports get consumed and/or processed in the region, it makes sense that the majority of the ~474,000 mt of global production winds up in the region.

The ROW produces ~162,000 mt of REE in actual weight. It exports ~134,000 mt and imports ~205,000 mt. This implies that the ROW consumes ~233,000 mt. An adjustment to Europe's data needs to be made. Estonia alone imports ~44,000 mt where one of Europe's only REE processing facilities is located. The exports from many of the countries within Europe likely equate to Estonia's imports and Estonia's exports are likely accounted for in some of the other European countries imports. Netting Estonia's total imports and exports of ~67,000 mt from the total estimated ROW consumption, generates a total ROW consumption or demand estimate of ~166,000 mt.

Based upon the above discussion and assumptions, in total the REE consumption market is estimated to be ~568,000 mt in actual weight. This estimate exceeds the estimated global production in mt of ~474,100 mt. However, the estimated global production is known to exclude sources of REE production from countries not covered by the USGS or the UN. The gap of ~93,000 mt between estimated global production and consumption can be considered to represent the unaccounted-for production.

Importantly, the analysis implies that the China/Southeastern region represents at least 70% of global REE consumption with the ROW at ~30%.

"Importantly, the analysis implies that the China/Southeastern region represents at least 70% of global REE consumption with the ROW at ~30%."

The China/Southeastern region produces ~65% of the global mined REE mixed concentrate and imports the vast majority of the REE concentrate produced by the ROW. China not only controls the globe's REE supply, but it, along with other countries in the Southeastern Asia region consume the majority of global REE supply as the region houses much of the globe's manufacturing capacity for end-use products that require REE. In addition, limited price transparency for REE products and the lack of futures market introduce even more uncertainty for a new entrant to adequately quantify the profitability potential of a new midstream and downstream REE extraction facility.

C. Prices

Due to China/Southeastern Asia's monopoly like market power over the global REE value chain, prices for concentrates and purity REE oxides/metals are determined in the region. This contributes to a lack of transparent REE price data. Typically, REE midstream extraction operators contract directly with the REE mixed concentrate suppliers and with manufacturers and end-users for the sale of the purity REE products. Because these are private contracts and nearly the entirety of demand resides in China/Southeast Asia, the raw data regarding the volume and price of those transactions are not publicly available. The data that exist are based upon surveys conducted by private research companies. Once such survey data are compiled, indicative prices are generated for the various REE purity products. The raw data are proprietary to the research company conducting the survey and compiling the results. Access to the derived indicative pricing information typically requires a subscription to the company's data service. There are a few sources for REE market price data. One source for historic and current REE oxides and metals price data is Asian Metals, Corp and its REE price data are used in this paper.

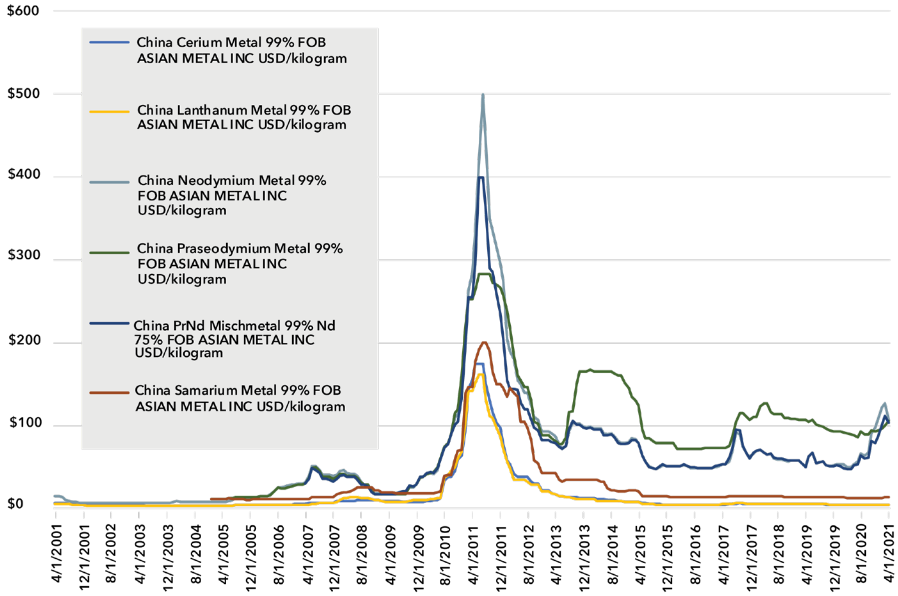
REE prices are based on purity and vary between individual REE products. Recall that marketed REE products include oxides, metals, mischmetal, and combinations thereof. Indicative prices for oxides and metals are available.

The prices for high purity individual streams of REE (i.e., 99%+) are premium to the less concentrated streams of REE. Thus, oxide prices are lower than REE purity metal prices. In addition, LREE prices tend to be much lower than HREE prices due to the scarcity of HREE compared to LREE. Recall that LREE include cerium, lanthanum, praseodymium, samarium and neodymium. The HREE include europium, dysprosium, thulium, and yttrium.

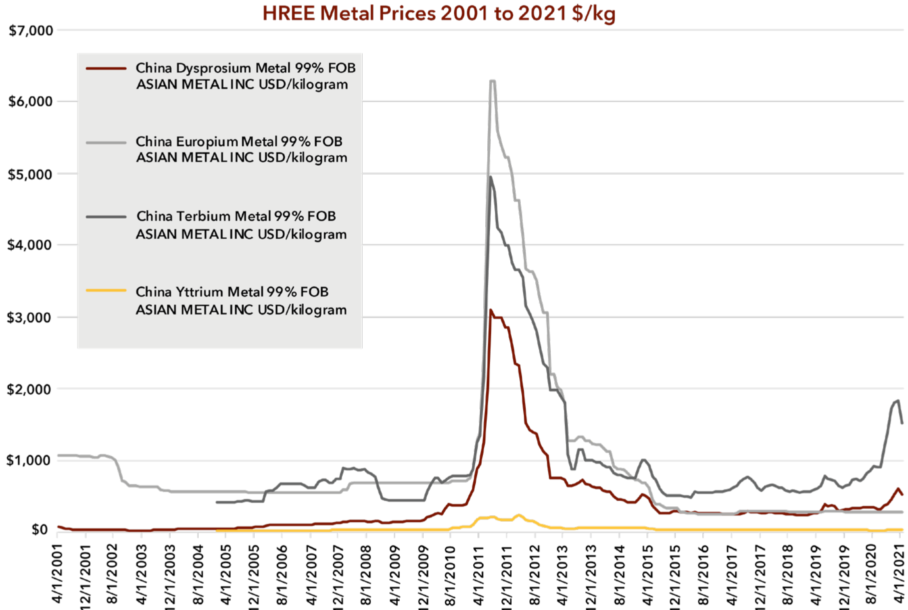
Graphs 4 and 5, below, show indicative REE metal prices from 2001 through 2021, divided between LREE and HREE.

Graphs 4 and 5: LREE and HREE Metal Prices from Asian Metals, Corp.

LREE Metal Prices 2001 to 2021 $/kg



HREE Metal Prices 2001 to 2021 $/kg



As can be seen, the LREE metals price range where neodymium posted a high price of $500/kg over the period, is significantly lower than the HREE metal price range, which bottoms around the same level and where europium metal traded as high as $6,000/kg.

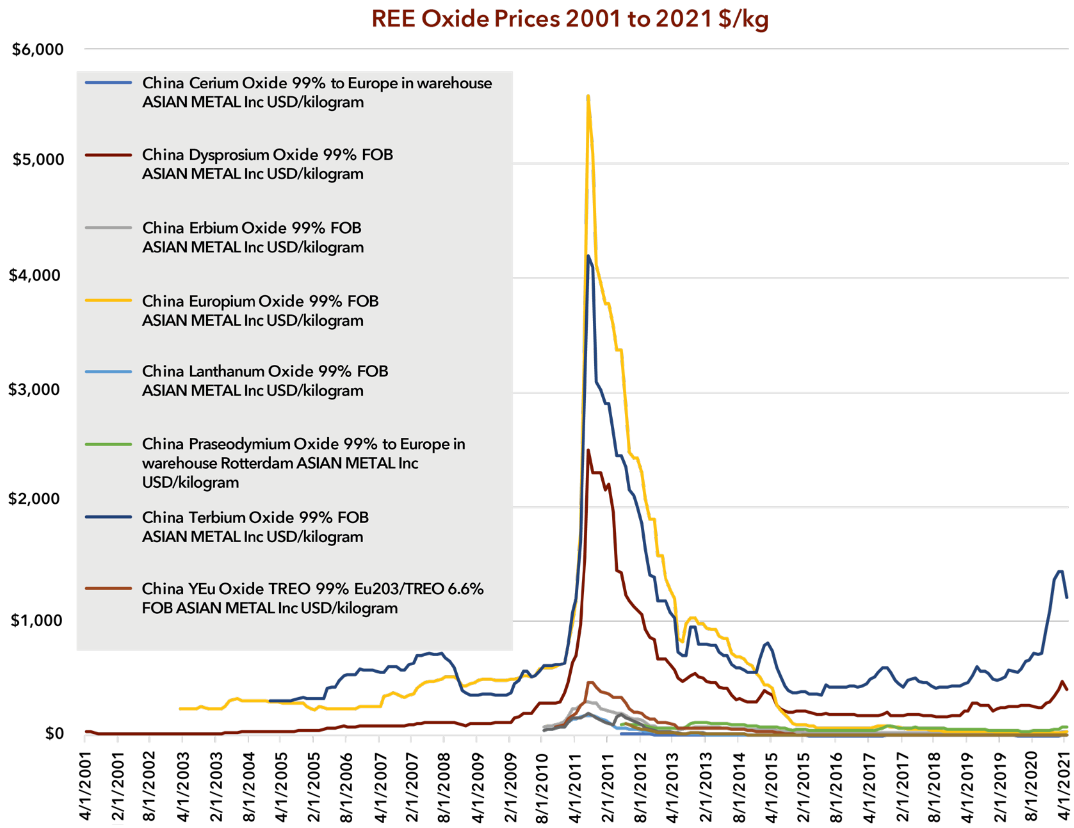
Metals prices were relatively stable from 2001 until 2010 and then increased exponentially in 2011, remained relatively high for a couple of years, and then moderated. HREE metals prices moderated to levels lower than 2010 prices. LREE metals prices moderated but have been higher overall and more volatile, particularly praseodymium, neodymium, and NdPr mischmetal, due to the significant increase in their application in the manufacturing of permanent magnets (as noted in the Executive Summary and explained more below).

The price spike experienced in 2011 occurred as a result of the Chinese government cutting the REE export quota by ~40%.[51] As noted previously, the WTO ruled against the legality of China's export quotas and China lifted the restrictions in 2015. The withholding of supply by the Chinese government created havoc in the global REE market. It induced companies and countries located outside of the region, and dependent upon the region for REE, to begin considering opening or re-opening operations.

REE oxide prices follow much the same pattern as the metals, particularly the HREE, dysprosium and europium. LREE oxide price data start in 2010. REE oxide prices and are shown in Graph 6.

> **"The price spike experienced in 2011 occurred as a result of the Chinese government cutting the REE export quota by ~40%."**

Graphs 6: REE Oxide Prices from Asian Metals, Corp.



Since 2015 REE metal and oxide prices stabilized closer to pre-2011 levels. The exceptions to that general trend are Nd, Pr, and combinations thereof, whose prices increased compared to pre-2011 levels. The demand for Nd and Pr, and combinations thereof, increased significantly due to the increase in the need for permanent magnets in many technological manufactured products, as discussed previously.

The price spikes led to more interest globally in the pursuit of alternative sources for REE, and more specifically, in mining REE in countries outside of China. It is no coincidence that Australian based Lynas ramped up its REE mining at the Mt. Weld Mine during that time and commissioned its Malaysian based REE separations plant in 2013. This is also the time

[51] Eggert, et al. "Rare Earths: Market Disruption, Innovation, and Global Supply Chains," Annual Review of Environment and Resources, August 9, 2016, p 10.1-10.24, p. 10.6.

when the Mountain Pass mine in the US began producing REE concentrate, after not producing for over a decade.

While prices have moderated since the spikes, China's ability to manipulate global REE prices through regulatory control over its own REE industry should serve as a stark reminder that it has many different policy options available, that if exercised will necessarily impact the global supply-demand balance for REE. These potential actions will have direct price implications on market suppliers and consumers. New entrants into the REE midstream and downstream sector must have a strategy to address and mitigate the implications of low prices and/or a lack of market buyers.

Project investment decisions cannot be made without a strong understanding of the underlying economics. While cash may be available to build a project, if the goal is for it to operate over the long term, there must be a plan for revenue generation that not only covers the projects ongoing operating costs, but also generates a return that can be reinvested in future growth. Under current market conditions, a new entrant into the REE midstream and downstream sector would be a de facto price taker. Future REE market prices are guaranteed to change and can just as easily decline below a level that covers costs, as they can increase. However, given that China continues to have excess mining capacity; idle midstream and downstream extraction capacity; the ability to enforce quotas; and a mission to manage its REE sector as a strategic resource, it has ample capacity to cause prices to decline to a point where a new entrant fails.

Establishing a REE supply chain outside of the China/Southeastern Asia region comes with a host of issues and challenges that must be addressed, including the lack of diversity in the pool of consumers. US government interest in a US-based REE supply chain is growing, and policies are being implemented that provide funding for US-based REE midstream and downstream processing. Among the many policy actions taken with respect to REE, as will be described in the following section, there has yet to be policy that specifically contemplates the long-term profitable operation of the new midstream projects receiving federal funding.

"While prices have moderated since the spikes, China's ability to manipulate global REE prices through regulatory control over its own REE industry should serve as a stark reminder that it has many different policy options available, that if exercised will necessarily impact the global supply-demand balance for REE."

Section V

Current Political and Policy Environment Surrounding REE

As discussed previously, domestic sources of REE are increasingly attractive and essential as a result of China's monopoly over the REE market and the anticipated increase in demand for REE-based products. Developing domestic sources of REE is now a bipartisan national priority, evident in both executive and congressional actions.

A. Executive Actions

Efforts to stymie China's monopoly over the REE market formally began when President Trump signed Executive Order 13817—*A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*—on December 20, 2017.[52]

Order 13817 explains that "[i]t shall be the policy of the Federal Government to reduce the Nation's vulnerability to disruptions in the supply of [CM]."[53] To accomplish this, the Order specifies that the US should identify new sources of CM; increase activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and processing CM; ensure that miners and producers have electronic access to advanced topographic, geologic, and geophysical data; and streamline leasing and permitting processes to expedite exploration, production, processing, reprocessing, recycling, and domestic refining of CM.[54] The Order also established a definition for CM. They are "non-fuel mineral[s] or mineral material[s] essential to the economic and national security of the United States," the "supply chain of which is subject to disruption," and "serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or our national security."[55] The Energy Act of 2020, passed as part of the Consolidated Appropriations Act in late 2020, codified this definition in statute and provided a process for establishing mineral criticality and the CM list itself.[56]

Under the direction of Order 13817 and in coordination with the Bureau of Land Management (BLM), the USGS published a list

[52] Proclamation No. 13817, 82 Fed. Reg. 60835 (December 26, 2017), https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf; Congress later directed the USGS to review and revise its methodology and list of critical minerals at least every three years. Pub. L. 116-260, § 7002(5)(A), Dec. 27, 2020 (Consolidated Appropriations Act, 2021), https://www.congress.gov/116/bills/hr133/BILLS-116hr133enr.pdf.
[53] Proclamation No. 13817, 82 Fed. Reg. at 60835-60836 (December 26, 2017), https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf.
[54] Proclamation No. 13817, 82 Fed. Reg. at 60835-60836 (December 26, 2017), https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf.
[55] Proclamation No. 13817, 82 Fed. Reg. at 60835-60836 (December 26, 2017), https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf.
[56] 30 USC.A. § 1606.

of thirty-five CM on May 18, 2018, which will be "updated periodically."[57] Most recently, the USGS revised the list in May of 2021 and published an updated list in November of 2021.58 The revised list was open to public comment until December of 2021.[59]

The original CM list served as the basis for *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (Federal Strategy)*, published by the Secretary of Commerce in June 2019.[60] The Federal Strategy report contains six "Calls to Action," twenty-four goals, and sixty-one recommendations that "describe specific steps that the Federal Government will take to achieve the objectives outlined in Executive Order 13817."[61] The "Calls to Action" include:

- advancing transformational research, development and deployment across critical mineral supply chains;
- strengthening America's critical mineral supply chains and defense industrial base;
- enhancing international trade and cooperation related to CM;
- improving the understanding of domestic critical mineral resources;
- improving access to domestic critical mineral resources on federal lands and reduce federal permitting timelines; and
- growing the American CM workforce[62]

The Federal Strategy notes that while all thirty-five of the recently listed CM are produced from conventional mining sources, some may also be obtained from underutilized secondary and/ or unconventional sources (e.g., coal byproducts such as fly ash).[63]

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[57] Proclamation No. 13953, 85 Fed. Reg. 62539 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf; Proclamation No. 13817, *supra* note 5. To formulate the list, the USGS used the White House Office of Science and Technology Council's *Mineral Criticality Screening Tool*, initially published by the White House in 2016 and updated annually by the USGS. (*see* Nat'l Science and Technology Council, Assessment of Critical Minerals: Updated Application of Screening Methodology (2018), https://trumpwhitehouse.archives.gov/wp-content/uploads/2018/02/Assessment-of-Critical-Minerals-Update-2018.pdf.

[58] https://pubs.er.usgs.gov/publication/ofr20211045; https://www.federalregister.gov/documents/2021/11/09/2021-24488/2021-draft-list-of-critical-minerals.

[59] https://pubs.er.usgs.gov/publication/ofr20211045; https://www.federalregister.gov/documents/2021/11/09/2021-24488/2021-draft-list-of-critical-minerals.

[60] Department of Commerce, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (2019), https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.

[61] Department of Commerce, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (2019), https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.

[62] Department of Commerce, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (2019) at 14-44, https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.

[63] Department of Commerce, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (2019) at 14-15, https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.

On July 22, 2019, President Trump issued a series of Presidential Determinations under § 303 of the Defense Production Act of 1950 (DPA).[64] These Determinations state that the "domestic production capability for [REE] . . . is essential to the national defense" and "[w]ithout Presidential action . . . United States industry cannot reasonably be expected to provide the production capability for [REE] adequately and in a timely manner."[65] While there was no specified funding, in late 2019 the US Army announced plans to support the construction of REE processing facilities in an effort to secure a domestic supply of the minerals used for military weapons and electronics.[66] Specifically, the Army indicated plans to fund up to two-thirds of a refiner's costs and at least one project, if not more.[67]

"These Determinations state that the "domestic production capability for [REE] . . . is essential to the national defense."

In April 2020, the DOE published a report on the REE supply chain where it highlighted its role in the *Federal Strategy*, provided a current summary of the state of the industry, explained challenges, and recommended next steps.[68] The Report noted the complex regulatory environment for permitting impedes increasing the production of domestic REE.[69] In August of the same year and in alignment with the *Federal Strategy*, the DOE announced $20 million in funding for five research projects focused on improving the efficiency of use and extraction of REE from geologic, recycled, and unconventional sources.[70]

In November of 2020, the DOD announced contracts with several REE producers, three falling under the DPA, to fund both research efforts and commercial development projects.[71] The DOD awarded TDA Magnetics and Urban Mining Company $2.3 million

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[64] Defense Production Act of 1950 § 303(a)(5), as amended, 50 U.SC. § 4533; 84 Fed. Reg. 35,967, 35,969, 35,971, 35,973, and 35,975 (July 25, 2019); Allyn G. Turner & Gary D. Holland, *President Moves to Secure Domestic Production and Processing of Rare Earth Elements*, XI The Nat'l L. Rev. 266 (2019), https://www.natlawreview.com/article/president-moves-to-secure-domestic-production-and-processing-rare-earth-elements.

[65] Proclamation No. 2019-18, 84 Fed. Reg. 35971 (July 25, 2019), https://www.govinfo.gov/content/pkg/FR-2019-07-25/pdf/2019-15999.pdf; Turner & Holland, *supra* note 14; Shane Lasely, *Trump: Rare earths essential to US defense*, Mining News (Sept. 26, 2020), https://www.miningnewsnorth.com/story/2019/08/01/news/trump-rare-earths-essential-to-us-defense/5845.html; 84 Fed. Reg. 35,967; 35,969; 35,971; 35,973; and 35,975 (July 25, 2019).

[66] Ernest Scheyder, *Exclusive: US Army will fund rare earths plant for weapons development*, Reuters (Dec. 10, 2019), https://www.reuters.com/article/us-usa-rareearths-army-exclusive/exclusive-u-s-army-will-fund-rare-earths-plant-for-weapons-development-idUSKBN1YF0HU.

[67] Ernest Scheyder, *Exclusive: US Army will fund rare earths plant for weapons development*, Reuters (Dec. 10, 2019), https://www.reuters.com/article/us-usa-rareearths-army-exclusive/exclusive-u-s-army-will-fund-rare-earths-plant-for-weapons-development-idUSKBN1YF0HU.

[68] US Department of Energy Efficiency & Renewable Energy, Critical Materials Rare Earths Supply Chain: A Situational White Paper (2020), https://www.energy.gov/sites/prod/files/2020/04/f73/Critical%20Materials%20Supply%20Chain%20White%20Paper%20April%202020.pdf.

[69] US Department of Energy Efficiency & Renewable Energy, Critical Materials Rare Earths Supply Chain: A Situational White Paper (2020), https://www.energy.gov/sites/prod/files/2020/04/f73/Critical%20Materials%20Supply%20Chain%20White%20Paper%20April%202020.pdf.

[70] ENERGY.GOV, DOE Awards $20 Million for Research on Rare Earth Elements (2020), https://www.energy.gov/articles/doe-awards-20-million-research-rare-earth-elements.

[71] US Department of Defense, DOD Announces Rare Earth Element Awards to Strengthen Domestic Industrial Base (2020), https://www.defense.gov/Newsroom/Releases/Release/Article/2418542/dod-announces-rare-earth-element-awards-to-strengthen-domestic-industrial-base/.

and $0.86 million, respectively, to study REE magnet supply chains and inventories.[72] In addition to these awards, the DOD has begun to study ways to transition defense supply chains to non-Chinese sources of REE magnets, create more domestic processing, partner with industry to establish domestic production of neodymium iron boron magnet production, and leverage funds to develop new REE technologies.[73]

Regarding funding for commercial development projects, the DOD earmarked the MP Materials Mountain Pass operation site for $9.6 million to establish domestic processing and separation capabilities for LREE, which will enable the facility to process nearly 12% of global REE content.[74]

President Trump signed another executive order on October 5, 2020—Executive Order 13953, *Assessing the Threat to the Domestic Supply Chain From Reliance on Critical Minerals From Foreign Adversaries and Supporting the Domestic Mining and Processing Industries*.[75] The Order highlights that the 35 previously identified CM "are indispensable to our country," but the US "presently lack[s] the capacity to produce them in processed form in the quantities . . . need[ed]."[76] It goes on to explain how China has used aggressive economic practices to encourage "industries that rely on these elements to locate their facilities, intellectual property, and technology in China."[77]

Order 13953 requires the Department of Interior (DOI), in consultation with the Secretaries of Treasury, Defense, Commerce, and other heads of Agencies, investigate "our Nation's undue reliance on critical minerals, in processed or unprocessed form, from foreign adversaries" and "submit a report to the President . . . within 60 days."[78] Thereafter, the Order directs the DOI to update the President every 180 days on the state of the threat posed by national reliance on CM and recommend actions, and it requires the DOI to submit recurring final reports to Congress.[79] Various other federal agencies are directed to analyze applicable law to see where it can be leveraged to: expand the domestic critical mineral supply chain, establish grant programs to install production and processing equipment in the US, and ensure loan guarantees under extant technology incentive programs.[80]

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[72] US Department of Defense, DOD Announces Rare Earth Element Awards to Strengthen Domestic Industrial Base (2020), https://www.defense.gov/Newsroom/Releases/Release/Article/2418542/dod-announces-rare-earth-element-awards-to-strengthen-domestic-industrial-base/.
[73] US Department of Defense, DOD Announces Rare Earth Element Awards to Strengthen Domestic Industrial Base (2020), https://www.defense.gov/Newsroom/Releases/Release/Article/2418542/dod-announces-rare-earth-element-awards-to-strengthen-domestic-industrial-base/.
[74] US Department of Defense, DOD Announces Rare Earth Element Awards to Strengthen Domestic Industrial Base (2020), https://www.defense.gov/Newsroom/Releases/Release/Article/2418542/dod-announces-rare-earth-element-awards-to-strengthen-domestic-industrial-base/.
[75] Proclamation No. 13953, 84 Fed. Reg. 62539, at 62539-62544 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf.
[76] Proclamation No. 13953, 84 Fed. Reg. 62539, at 62539 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf.
[77] Proclamation No. 13953, 84 Fed. Reg. 62539, at 62540 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf.
[78] Proclamation No. 13953, 84 Fed. Reg. 62539, at 62540 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf.
[79] Proclamation No. 13953, 84 Fed. Reg. 62539, at 62540-41 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf.
[80] Proclamation No. 13953, 84 Fed. Reg. 62539, at 62540-43 (Oct. 5, 2020), https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf.

In President Biden's first few months of leadership, he issued an *Executive Order on America's Supply Chains* declaring "it is the policy of [his] Administration to strengthen the resilience of America's supply chains."[81] Order 14017 required a 100-day supply chain review, which included a requirement that the DOD, in consultation with other heads of agencies, "submit a report identifying risks in the supply chain for critical minerals . . . and policy recommendations to address these risks" to support and update Executive Order 13953.[82]

Recent agency actions continue the trend to fund REE research and commercial development. In February 2021, the DOD gave an additional award of $30.4 million under the DPA to Lynas for the establishment of a LREE separation capacity in Texas through its wholly-owned subsidiary, Lynas USA LLC.[83] It is anticipated that Lynas could produce a quarter of the world's supply of REE upon completion of the project.[84] In April 2021, the DOE awarded $19 million to 13 projects in traditionally fossil fuel-producing communities for the study of REE.

B. Legislative Actions

Congress has also demonstrated its dedication to cultivating a domestic REE supply as evidenced by the introduction and passage of recent legislation. In 2017, a bipartisan bill that increased federal "spending on technology research and development amid rising competition from China and other nations" was passed.[85] Following this, Congress appropriated $167 million and in $199 million for fiscal years 2019 and 2020, respectively, for "Energy Efficiency and Renewable Energy-Research and Development" activities, "which include those of [DOE's Critical materials Institute (CMI)]," a DOE energy Innovation Hub formed in 2013 and led by Ames Laboratory.[86]

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[81] Proclamation No. 14017, 86 Fed. Reg. 11849 (Feb. 24, 2021), https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/.

[82] Proclamation No. 14017, 86 Fed. Reg. 11849 (Feb. 24, 2021), https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/.

[83] US Department of Defense, DOD Announces Rare Earth Element Awards to Strengthen Domestic Industrial Base (2021), https://www.defense.gov/News/Releases/Release/Article/2488672/dod-announces-rare-earth-element-award-to-strengthen-domestic-industrial-base/.

[84] US Department of Defense, DOD Announces Rare Earth Element Awards to Strengthen Domestic Industrial Base (2020), https://www.defense.gov/Newsroom/Releases/Release/Article/2418542/dod-announces-rare-earth-element-awards-to-strengthen-domestic-industrial-base/.

[85] John D. McKinnon, *Senate Approves $250 Billion Bill to Boost Tech Research*, The Wall Street Journal (June 8, 2021), https://www.wsj.com/articles/senate-approves-250-billion-bill-to-boost-tech-research-11623192584?mod=article_inline; Pub. L. 114-329, Jan. 6, 2017 (American Innovation and Competitiveness Act), https://www.congress.gov/114/plaws/publ329/PLAW-114publ329.pdf.

[86] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 14, https://crsreports.congress.gov/product/pdf/R/R46618 (citing 8 US Department of Energy (DOE), FY2019 Congressional Budget Justification, Volume 3 Part 2, 2018, p. 176, DOE, Congressional Budget Request, Volume 3 Part 2, 2019, p. 166, and DOE, FY2021 Congressional Budget Request, Volume 2, 2020, p. 250).

Additionally, a number of bills were introduced in both the House and the Senate in the 116th legislative session.[87] While none of these measures ultimately became law, common themes emerged. The bills addressed:

- Appropriations for REE-related issues in amounts ranging from $50 million to $135 million per fiscal year, with funding continued for four to eight years;[88]
- Establishing "guidance for the acquisition of items containing rare-earth materials and the supply chain of rare-earth materials from countries that are not US adversaries;"[89]
- DOE grant programs to encourage battery recycling research, development, and demonstration;[90]
- Researching processes to extract REE from coal and coal byproducts (formalization of an ongoing research—the Clean Coal and Carbon Management Program—in the National Energy Technology Laboratory);[91]
- Creating a federally chartered, but privately funded, corporation and cooperative to mitigate the high costs associated with extracting REE from minerals in radioactive elements (e.g., thorium and uranium) by engaging in storage and processing activities;92 and
- Enacting tax incentives for firms investing in domestic REE extraction.[93]

[87] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 14, https://crsreports.congress.gov/product/pdf/R/R46618; Brandon S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 14-17, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf (referencing S. 1317; H.R. 4410; H.R. 2531; H.R 3405; H.R. 3567; S. 3356; S. 2657; H.R. 4447; S. 3694; S. 4537; H.R. 7812; S. 3694; S. 4537; H.R. 7812; H.R. 8143; S. 2093; and H.R. 4410, 116th Cong. (2019-2020)).

[88] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 13, https://crsreports.congress.gov/product/pdf/R/R46618.

[89] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 13-16, https://crsreports.congress.gov/product/pdf/R/R46618.; Brandon S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 14-16, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf.

[90] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 13-16, https://crsreports.congress.gov/product/pdf/R/R46618.; Brandon S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 14-16, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf.

[91] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 13-16, https://crsreports.congress.gov/product/pdf/R/R46618.; Brandon S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 14-16, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf; *See also* S. 1052, 116th Cong. (2019-2020).

[92] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 13-16, https://crsreports.congress.gov/product/pdf/R/R46618; Brandon S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 14-16, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf.

[93] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 13-16, https://crsreports.congress.gov/product/pdf/R/R46618; Brandon

At present, there are a few pieces of federal legislation either proposed or passed that support developing domestic sources of REE or that attempt to modify current mining law.[94] The legislation directed at developing domestic sources of REE embraces the idea that "[r]educing taxes assessed on commercial activities is a potential means of stimulating investment . . . [because] sectors with high initial costs, such as mines and ore refining operations, may be accelerated if tax incentives allow for earlier expected profitability."[95]

"At present, there are a few pieces of federal legislation either proposed or passed that support developing domestic sources of REE or that attempt to modify current mining law."

First, the *Rare Earth Magnet Manufacturing Production Tax Credit Act* (H.R. 5033) would create a new tax credit for the production of rare earth magnets at $20 to $30 per kilogram of rare earth magnets produced in the US, including a direct payment option, and be available after December 2021.[96] The credit would phase out for magnets produced after December 2030 and would not be available if any REE-component materials were produced in a non-allied foreign nation.[97]

Second, H.R. 2688 the *Rare Act* would encourage domestic production of REE. It aims to do this by: Providing full expensing (§ 168(k) of the IRC) for property used in REE extraction in the US; providing a permanent full expensing (under new § 168(n) of the IRC) for nonresidential property used for mining REE within the US; providing a deduction for the purchase of CM and REE extracted within the US (under new § 177 of the IRC); increasing the rate of percentage depletion allowable (§ 613(b)(1) of the IRC) in the US; and establishing a grant program to develop CM and metals.[98]

Third, and notable because this piece of legislation was passed, is the *Infrastructure Investment and Jobs Act* of 2021.[99] Passed in early November, this legislation includes large appropriations for research and demonstration facilities, programs, and commercial development facilities.[100]

S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 14-16, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf.

[94] Greg Matlock, *Proposed US Legislation Could Encourage Mining of Rare Earth Metals*, Mayer Brown (Sept. 2021), https://www.mayerbrown.com/en/perspectives-events/publications/2021/09/proposed-us-legislation-could-encourage-mining-of-rare-earth-metals.

[95] Brandon S. Tracy, *An Overview of Rare Earth Elements and Related Issues for Congress*, Congressional Research Service (Nov. 24, 2020) at 2, 14-15, https://crsreports.congress.gov/product/pdf/R/R46618; Brandon S. Tracy, *Policy Topics and Background Related to Mining on Federal Lands*, Congressional Research Service (Mar. 19, 2020) at 15-16, https://www.everycrsreport.com/files/20200319_R46278_260b66639d974c6f865fe13406b7809df49fa489.pdf.

[96] Greg Matlock, *Proposed US Legislation Could Encourage Mining of Rare Earth Metals*, Mayer Brown (Sept. 2021), https://www.mayerbrown.com/en/perspectives-events/publications/2021/09/proposed-us-legislation-could-encourage-mining-of-rare-earth-metals; H.R. 5033, 117th Cong. (2021) (Rare Earth Magnet Manufacturing Production Tax Credit Act of 2021), https://www.congress.gov/bill/117th-congress/house-bill/5033?q=%7B%22search%22%3A%5B%22H.R.+5033%22%5D%7D&s=1&r=1.

[97] Greg Matlock, *Proposed US Legislation Could Encourage Mining of Rare Earth Metals*, Mayer Brown (Sept. 2021), https://www.mayerbrown.com/en/perspectives-events/publications/2021/09/proposed-us-legislation-could-encourage-mining-of-rare-earth-metals.

[98] Greg Matlock, *Proposed US Legislation Could Encourage Mining of Rare Earth Metals*, Mayer Brown (Sept. 2021), https://www.mayerbrown.com/en/perspectives-events/publications/2021/09/proposed-us-legislation-could-encourage-mining-of-rare-earth-metals.

[99] https://www.congress.gov/bill/117th-congress/house-bill/3684/text.

[100] https://www.congress.gov/bill/117th-congress/house-bill/3684/text.

Regarding modifications to current mining law, there have been numerous attempts to repeal or amend the General Mining Law (GML) of 1872, which applies to hardrock mining of "locatable" minerals on federal public lands—the category most conventionally sourced CM and REE deposits fall under.[101] The law was originally passed to encourage westward expansion and settlement of federal public lands, affording claimants who located "valuable" mineral deposits the opportunity to either *possess* the lands for the purpose of developing the minerals or *purchase* the lands for the purpose of developing the minerals. While the option to patent the mineral claim and attain ownership is no longer available, this process stands in stark opposition to the development of other minerals on federal public lands—like oil, gas, coal, and others—for which a lease must be obtained to develop the minerals and the claimant must pay the federal government royalties on extraction.

The most recent attempt to modify the GML of 1872 was proposed in the October 28th House Committee Revision of the Build Back Better Act, which, as written, would have added a 2% royalty on any mining claim, concentrate, or product derived from locatable minerals on federal lands.[102] The House Rules Committee Revision on November 3rd struck the royalty provision, which is no longer contained in the Build Back Better Act as it is written now.[103] However, given the recognized importance of REE to both national security and the energy sector, it is safe to expect continued attention on amending the GML in years to come.

In the past decade, US momentum to match and resist China's growing economic influence, particularly over the REE market, has grown to the point where competing against China is a priority.[104] It is no surprise that the US recently secured a three-way alliance with Australia and the UK to deploy nuclear-powered submarines in the Pacific Ocean to "reinforce alliances and update them as strategic priorities shift."[105] The US

[101] General Mining Law of 1872, 30 U.S.C. §§ 21-54, §§ 611-615.

[102] https://rules.house.gov/sites/democrats.rules.house.gov/files/CP-117HR5376RH-COMPARED-RCP117-18_.pdf.

[103] https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-117HR5376RH-RCP117-18.pdf.

[104] Jacob M. Schlesinger, *What's Biden's New China Policy? It Looks a Lot Like Trump's*, The Wall Street Journal (Sept. 22, 2021) https://www.wsj.com/articles/whats-bidens-china-policy-it-looks-a-lot-like-trumps-11599759286; *The Daily: Submarines and Shifty Allegiances*, The New York Times (Sept. 22, 2021) at 12:00 - 12:52 (stating "Even back in 2010 2011, it was very apparent to the Obama administration that the real long-term challenge for the US was in China."); at 14:40 – 17:23 (stating "President Trump came in with . . . a very strong China focus of his own but his focus was very driven by trade."; ". . . [he was] in fact continuing a trend that began under the Obama administration, just with a different public tone, a different public posture, and an emphasis on the commercial relationship, rather than the security relationship [or] the military relationship."; ". . . to some extent, both administrations Obama and Trump, had other distractions that never let them really put the focus on . . . what both Presidents temperamentantly (sic.) wanted to do, which was keep the focus very much on China."); and at 17:30 – 19:40 "Biden is a believer in alliances . . . but he also spent a lot of time traveling to China and that really helped develop his views and sharpen his views about China's role in this world."; "China during this period is acting increasingly threateningly toward its neighbors, its militarizing more and more of the coastal waters around it, . . . so China is looking more and more threatening to its neighbors. . . . so when [Biden] comes into office he . . . wants to finally put the full focus of American foreign policy on this competition with China."); at 21:53 - 22:20 (Stating ". . . the Biden administration concluded in a fairly cold-blooded transactional way, that getting involved in a submarine deal with Australia with nuclear-powered submarines just made a lot of sense, it was an important play. . . in this competition with China . . .").

[105] Mark Landler, *Submarine Deal Gives Post-Brexit Britain Its Moment on the Global Stage*, The New York Times (Sept. 18, 2021), https://www.nytimes.com/2021/09/18/world/europe/britain-us-france-submarines-

supply of REE is presently highly dependent on transportation routes of large commercial bulk carrier ships that travel through the Pacific Ocean.[106]

Take for example, the DOD's recent investment of $30 million toward funding the construction of Lynas Rare Earth's processing plant in Hondo, Texas.[107] As a result of the deal, the US will receive shipments of unprocessed REE from the Lynas Mount Weld mine in Australia until the Lynas processing facility in Western Australia is operational.[108] The project requires safe, efficient, and secure passage from Freemantle, Australia to Galveston, Texas—passing through 15,000 nautical miles of the Pacific Ocean and "through sea lanes of strategic interest to China."[109] China's increased naval presence and historical influence over REE shipments could inhibit or slow shipments, which may increase the cost of the commodity, a concern flagged by the US Navy at the end of last year.[110] Despite the seven REE processing plants scoped for development in the US, reaching commercial viability is expected to be a challenge with limitations presenting in the form of achieving consistent REE quality, production efficiency, and affordable costs.[111]

While it remains to be seen whether pending legislative bills will ultimately become law, the tenor of REE policy support seems to have turned a corner in the past decade, with the federal government determined to foster and support a domestic REE supply chain. Federal funding continues to focus on developing both conventional hardrock sources of REE as well as unconventional sources of REE. States with REE-rich resources, whether in conventional or unconventional form, may be interested in developing facilities to aid the domestic supply of the resources.

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brexit.html; Roger Cohen, *In Submarine Deal With Australia, US Counters China but Enrages France*, The New York Times (Sept. 16, 2021), https://www.nytimes.com/2021/09/16/world/europe/france-australia-uk-us-submarines.html.

[106] Eric Tegler, *The US Is Trying To Secure Rare Earth Elements For National Security, That Goes Beyond Simple Investment,* Forbes (Feb. 26, 2021) https://www.forbes.com/sites/erictegler/2021/02/26/the-us-is-trying-to-secure-rare-earth-elements-for-national-security-that-goes-beyond-simple-investment/?sh=3faae2845c53.

[107] Eric Tegler, *The US Is Trying To Secure Rare Earth Elements For National Security, That Goes Beyond Simple Investment,* Forbes (Feb. 26, 2021) https://www.forbes.com/sites/erictegler/2021/02/26/the-us-is-trying-to-secure-rare-earth-elements-for-national-security-that-goes-beyond-simple-investment/?sh=3faae2845c53.

[108] Eric Tegler, *The US Is Trying To Secure Rare Earth Elements For National Security, That Goes Beyond Simple Investment,* Forbes (Feb. 26, 2021) https://www.forbes.com/sites/erictegler/2021/02/26/the-us-is-trying-to-secure-rare-earth-elements-for-national-security-that-goes-beyond-simple-investment/?sh=3faae2845c53.

[109] Eric Tegler, *The US Is Trying To Secure Rare Earth Elements For National Security, That Goes Beyond Simple Investment,* Forbes (Feb. 26, 2021) https://www.forbes.com/sites/erictegler/2021/02/26/the-us-is-trying-to-secure-rare-earth-elements-for-national-security-that-goes-beyond-simple-investment/?sh=3faae2845c53.

[110] Eric Tegler, *The US Is Trying To Secure Rare Earth Elements For National Security, That Goes Beyond Simple Investment,* Forbes (Feb. 26, 2021) https://www.forbes.com/sites/erictegler/2021/02/26/the-us-is-trying-to-secure-rare-earth-elements-for-national-security-that-goes-beyond-simple-investment/?sh=3faae2845c53.

[111] Eric Tegler, *The US Is Trying To Secure Rare Earth Elements For National Security, That Goes Beyond Simple Investment,* Forbes (Feb. 26, 2021) https://www.forbes.com/sites/erictegler/2021/02/26/the-us-is-trying-to-secure-rare-earth-elements-for-national-security-that-goes-beyond-simple-investment/?sh=3faae2845c53.

Section VI

Current REE Projects in the US

Seven REE mining and/or mid-stream separations and concentrations projects are currently under evaluation or under active development in the US. At least four of those projects have received federal funding. A summary of the projects is provided in Table 4 below:

Table 4: US REE Production/Separations and Concentrations Projects

	Project	Deposit	State	Cost	Rare Earth Output	Production	Estimated in Service	Government Funding	Government Agency
1	MP Materials Restart of Mothballed REE Separations and Concentrations Plant	Mountain Pass Mine	CA	$200 million	LREE/NdPr	> 5,000 TPA	2023	$9.6 million	DOD
2	Rare Earth Resources Building of REE Separations and Concentrations Plant	Bear Lodge	WY	$44 million	LREE/NdPr	~7,000 TPA		$21.9 million	DOE
3	Lynas Rare Earths and Blue Line Corp. Bulding of LREE Separations and Concentrations Plant	Concentrate from Australia	TX		LREE	>5,000 TPA		$30 million	DOD
4	Lynas Rare Earths and Blue Line Corp. Bulding of HREE Separations and Concentrations Plant	Concentrate from Australia	TX		HREE			not published	DOD
5	Texas Minerals Resources Corp and USA Rare Earth	Round Top Mine	TX	$350.4 million	LREE/NdPr	247 TPA			
6	NioCorp Developments Inc. Elk Creek Mine and Separations and Concentrations Plant	Elk Creek Mine	NE	$1 billion	Nb, Sc, Ti	95 TPA			
7	Ucore Rare Metals Inc. Bokan Mine and Separations and Concentrations Plant	Bokan Mine	AK		HREE			$145 million	State of AK

Two of the separations and concentrations projects receiving federal funding are associated with the two proven REE reserves in the US – the Mountain Pass Mine in CA and the Bear Lodge deposit in WY. Two other projects – both with Australian based Lynas – will bring REE concentrate from abroad to the US to be processed.

While the current REE projects and federal funding for them are encouraging steps and supporting the establishment of a US-based REE supply chain, if downstream demand/consumption does not materialize in the US or in a country outside of the China/Southeastern Asia region, the vast majority of the purified and concentrated REE will have to be exported to the China/Southeastern Asia region to be applied in its manufacturing sector.

The structural threat presented by China/Southeastern Asia's monopoly power over the current REE market where a nascent REE supplier outside of the region could easily be forced into bankruptcy, necessitates that REE supply chain infrastructure investment in countries outside the region be coupled with firm, long-term downstream buyers for its output.

Conclusion and Next Paper

This paper documents the unique nature of the REE market, from the physical process of rendering REE usable to the downstream consumption of REE. The global REE market is currently controlled by the China/Southeastern Asia region where more than 60% of mined REE is produced and at least 70% of REE is consumed. The region's current monopoly power over the global REE value chain grew with increased Chinese government control over its REE industry and its willingness to accept the environmental impacts associated with the extraction of REE.

The ROW currently depends upon the China/Southeastern Asia region for purity REE and for manufactured products that employ REE. China's wielding of its market power in the 2010/2011 time frame, when the government restricted REE exports thus causing REE price spikes, was a clear sign of its willingness to employ policy to manipulate the global REE market.

US dependence upon the China/Southeastern Asia region for REE has been recognized as a national security issue. The recent flurry of Executive and Legislative policy directed towards the study and development of an REE supply chain by the US government, illustrates the growing importance of and interest in securing a US-based source. However, a real and obvious barrier to the successful, long-term operation of such a supply chain is the lack of an end-use product manufacturing sector outside of the China and Southeastern Asia region.

As the paper highlights, demand for REE is poised to continue to grow significantly, primarily driven by permanent magnet manufacturing. The globe's current permanent magnet manufacturing capacity is nearly all located in China.

Given the governmental and private funding being directed towards the development of US-based REE midstream and downstream REE extraction projects, for those projects to serve their overall long-term purpose – a US-based REE supply chain that mitigates dependence upon foreign sourced REE – strategies must be employed that ensure the REE output from the various projects have secure long-term buyers. There are various approaches that can be pursued to achieve this outcome, including governmental policy.

Wyoming's Bear Lodge Deposit has been tested and verified as a viable source for REE material and there is a stockpile of REE mined mixed concentrate at the mine awaiting further processing. However, a purifications/concentrations operation has yet to be built. Rare Element Resources, the owner of the Bear Lodge Mine, estimates the cost to build the facility at $44 million. The DOE has committed to funding $21.9 million for the engineering, construction, and operation[112] of a REE separations and concentrations demonstration plant (see Table 4), though the project is not guaranteed to succeed. A recommendation of the next paper is that the project should prioritize securing a long-term sustainable buyer for the purity output to ensure that the demonstration plant transforms into a long-term going concern.

[112] https://miningconnection.com/surface/news/article/rare_element_resources_named_doe_funding_recipient_for_rare_earth_separatio/.

Wyoming has many attributes that make it a favorable location for a US-based REE supply chain hub, including its own REE deposit and a host of potential unconventional sources for REE. The second paper will examine Wyoming's REE resources, focusing primarily upon the Bear Lodge deposit; identify the issues associated with creating and sustaining a commercially viable REE operation in Wyoming inclusive of an examination of mining law; explore many of the unique characteristics of Wyoming that make it the ideal location for a US REE supply chain hub; and describe specific mechanisms that could support the successful implementation of a fully integrated REE supply chain in Wyoming.

There remain technical, policy and economic challenges to building and sustaining a US-based REE industry that encompasses the full value chain. However, given the national security benefits, the need for these materials for energy and other industries, and the potential benefit to communities, it is most certainly worth continuing to undertake the steps necessary to make a robust, secure, US REE industry a reality.

"Wyoming has many attributes that make it a favorable location for a US-based REE supply chain hub, including its own REE deposit and a host of potential unconventional sources for REE."

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