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MEMORANDUM

DEPUTY MINISTER'S ROUNDTABLE ON CRITICAL MINERALS
AND A CANADA-US JOINT ACTION PLAN
(Information only)

ISSUE

To provide a debrief on the meeting that took place on August 7, 2019.

BACKGROUND

On June 20, 2019, Prime Minister Trudeau and President Trump committed to develop a joint action plan on critical minerals collaboration. In this context, the leaders discussed the need to improve mineral security, ensure the future competitiveness of industries, and highlighted a desire to ensure secure and reliable supply chains.

The announcement followed the release of the *US Critical Mineral List* (2018) and the *US Federal Strategy to Ensure a Reliable Supply of Critical Minerals* (June 2019), which highlight the increasing US focus on securing supplies of minerals essential to economic prosperity and national security (**Annex A**).

Of particular interest to Canada in the *US Federal Strategy*, is the Call to Action options for accessing and developing critical minerals through investment and trade with allies. Of the 35 mineral commodities deemed critical to the US, Canada is identified as a major import source for 13 minerals and the leading import source for 5 minerals. This includes US dependence on Canada for 100% imports of cesium, which is used for drilling fluids in the oil industry and in atomic clocks, and rubidium, which has a variety of applications including photocells and electronic tubes.

National Resources Canada (NRCan) convened an interdepartmental DM-level meeting (agenda and deck attached at **Annex B** and **C**) to discuss the issue and the way forward.

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CONSIDERATIONS



NEXT STEPS

PS is part of the task team that NRCan is currently establishing and will keep you apprised of developing issues.

Should you require additional information, please do not hesitate to contact me.



Enclosures: (3)

UNCLASSIFIED

Summary: Critical Minerals in the United States

The US is reliant on imports of certain mineral commodities that are vital to the nation's security and economic prosperity. This dependency on foreign sources creates a strategic vulnerability for both its economy and military to adverse foreign government action, natural disaster, and other events that can disrupt supply of these key minerals.

In May 2018, the US Department of the Interior presented a list of 35 mineral commodities deemed critical. The US is import-reliant (imports are greater than 50 percent of annual consumption) for 31 of these 35 minerals. China is identified as a major import source for 20 of them, and is the leading import source for 10. For 14 critical minerals, the US has no domestic production and relies completely on imports.

Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals

In December 2017, President of the United States issued an Executive Order directing the Secretary of Commerce to develop a strategy to reduce reliance on critical minerals and reduce vulnerability to disruptions in the supply chain.

In June 2019, the Secretary of Commerce released a report entitled *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, which presents six Calls to Action, 24 goals, and 61 recommendations that describe specific steps that the Government will take to achieve the objectives outlined in the Executive Order.

The Calls to Action include:

1. Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains;
2. Strengthen America's Critical Mineral Supply Chains and Defense Industrial Base;
3. Enhance International Trade and Cooperation Related to Critical Minerals;
4. Improve Understanding of Domestic Critical Mineral Resources;
5. Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes; and
6. Grow the American Critical Minerals Workforce.

**A Federal Strategy to Ensure Secure
and Reliable Supplies of Critical
Minerals**

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Executive Summary

The assured supply of critical minerals¹ and the resiliency of their supply chains are essential to the economic prosperity and national defense of the United States. The United States is heavily dependent on foreign sources of critical minerals and on foreign supply chains resulting in the potential for strategic vulnerabilities to both our economy and military. Mitigating these risks is important and consistent with our country's National Security Strategy and National Defense Strategy to promote American prosperity and to preserve peace through strength.

The United States imports most critical mineral commodities. Specifically, the United States is import-reliant (imports are greater than 50 percent of annual consumption) for 31 of the 35 minerals designated as critical by the Department of the Interior.² The United States does not have any domestic production and relies completely on imports to supply its demand for 14 critical minerals.³

To address this problem and reduce the Nation's vulnerability to disruptions in the supply of critical minerals, President Donald J. Trump issued Executive Order 13817, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, on December 20, 2017. The Executive Order directs the Secretary of Commerce, in coordination with heads of selected executive branch agencies and offices, to submit a report to the President that includes:

- (i) "a strategy to reduce the Nation's reliance on critical minerals;
- (ii) an assessment of progress toward developing critical minerals recycling and reprocessing technologies, and technological alternatives to critical minerals;

¹ As defined in Executive Order 13817, a critical mineral is "a mineral identified by the Secretary of the Interior [pursuant to the Executive Order] to be (i) a non-fuel mineral or mineral material essential to the economic and national security of the United States, (ii) the supply chain of which is vulnerable to disruption, and (iii) that 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." 82 Fed. Reg. 60835; 2017;
<https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals>

² Department of the Interior, "Final List of Critical Minerals 2018," 83 Fed. Reg. 23295; 2018,
<https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018>

³ U.S. Geological Survey, "Mineral Commodity Summaries 2018," 2018,
<https://doi.org/10.3133/70194932>

- (iii) options for accessing and developing critical minerals through investment and trade with our allies and partners;
- (iv) a plan to improve the topographic, geologic, and geophysical mapping of the United States and make the resulting data and metadata electronically accessible, to the extent permitted by law and subject to appropriate limitations for purposes of privacy and security, to support private sector mineral exploration of critical minerals; and
- (v) recommendations to streamline permitting and review processes related to developing leases; enhancing access to critical mineral resources; and increasing discovery, production, and domestic refining of critical minerals."

This report, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, presents 6 Calls to Action, 24 goals, and 61 recommendations that describe specific steps that the Federal Government will take to achieve the objectives outlined in Executive Order 13817.

When executed, this strategy will improve the ability of the advanced technology, industrial, and defense manufacturing sectors that use critical minerals to adapt to emerging mineral criticality issues; reduce risks for American businesses that rely on critical minerals; create a favorable U.S. business climate for production facilities at different stages of critical mineral supply chains; and support the economic security and national defense of the United States; all of which will reduce the Nation's vulnerability to critical mineral supply disruptions.

The Calls to Action outlined in this Strategy are listed below.

1. **Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains:** Assesses progress toward developing critical minerals recycling and reprocessing technologies, technological alternatives to critical minerals, source diversification, and improving processes for critical mineral extraction, separation, purification, and alloying.
2. **Strengthen America's Critical Mineral Supply Chains and Defense Industrial Base:** Discusses ways to improve critical mineral supply chains, which could help reduce risks to U.S. supply by increasing domestic critical mineral resource development, building robust downstream manufacturing capabilities, and ensuring sufficient productive capacity.
3. **Enhance International Trade and Cooperation Related to Critical Minerals:** Identifies options for accessing and developing critical minerals through investment and trade with America's allies, discusses areas for international

collaboration and cooperation, and ensures robust enforcement of U.S. trade laws and international agreements that help address adverse impacts of market-distorting foreign trade conduct.

4. **Improve Understanding of Domestic Critical Mineral Resources:** Provides a plan to: improve and publicize the topographical, geological, geophysical, and bathymetrical mapping of the United States; support mineral information collection and analysis of commodity-specific mitigation strategies; focus and prioritize interagency efforts; and conduct critical mineral resource assessments to support domestic mineral exploration and development of conventional sources (minerals obtained directly through mining an ore), secondary sources (recycled materials, post-industrial, and post-consumer materials), and unconventional sources (minerals obtained from sources such as mine tailings, coal byproducts, extraction from seawater, and geothermal brines) of critical minerals.
5. **Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes:** Provides recommendations to streamline permitting and review processes related to developing mining claims or leases and enhancing access to domestic critical mineral resources.
6. **Grow the American Critical Minerals Workforce:** Discusses the activities related to critical minerals needed to develop and maintain a strong domestic workforce to foster a robust domestic industrial base.

Introduction

Critical minerals⁴ are needed for many products used by Americans in everyday life, such as cell phones, computers, automobiles, and airplanes. These minerals are also used to make many other products important to the American economy and defense, including advanced electronics; manufacturing equipment; electricity generation, storage, and transmission systems; transportation systems; defense systems and other military supplies; cutting-edge medical devices; and other critical infrastructure systems.

The assured supply of these critical minerals, and the resiliency of their supply chains, are essential to the United States' economic security and national defense. As shown in Figure 1, the United States is heavily dependent on foreign sources of critical minerals. Specifically, the United States is import-reliant (imports are greater than 50 percent of annual consumption) for 31 of the 35 minerals designated as critical by the Department of the Interior (DOI).⁵ The United States does not have any domestic production and relies completely on imports to supply its demand for 14 critical minerals.

Mitigating risks associated with foreign dependence on sources of critical minerals is important and consistent with the National Security Strategy⁶ and National Defense Strategy⁷ to promote American prosperity and to preserve peace through strength. The dependency of the United States on foreign sources of critical minerals creates a strategic vulnerability for both our economy and our military with respect to adverse foreign government actions, natural disasters, and other events that could disrupt supply.

⁴ As defined in Executive Order 13817, a critical mineral is "a mineral identified by the Secretary of the Interior [pursuant to the Executive Order] to be (i) a non-fuel mineral or mineral material essential to the economic and national security of the United States, (ii) the supply chain of which is vulnerable to disruption, and (iii) that 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." 82 Fed. Reg. 60835; 2017; <https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals>

⁵ Department of the Interior, "Final List of Critical Minerals 2018," 83 Fed. Reg. 23295; 2018, <https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018>

⁶ Trump, Donald J., "National Security Strategy of the United States of America," 2017, <https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf>

⁷ Department of Defense, "Summary of the 2018 National Defense Strategy of the United States of America," 2018, <https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>

All stages of the critical mineral supply chain are important and can impact one another. For example, increasing the rate of mining without increasing corresponding processing and manufacturing capabilities will simply move the source of economic and national security risk further down the supply chain and create dependence on foreign sources for these capabilities.

Commodity	Net Import Reliance (%)		Major import sources (2013-16), share of net import reliance (%) ¹	Imports 2017 ²
ARSENIC (As ₂ O ₃)	100		Morocco, 52; China, 41; Belgium, 6; other, 1	7300
CESIUM	100		Canada, 100	NA
FLUORSPAR	100		Mexico, 71; China, 8; South Africa, 8; Vietnam, 5; other, 8	460,000
GALLIUM	100		China, 33; Germany, 23; United Kingdom, 22; Ukraine, 17; other, 5	22
GRAPHITE (natural)	100		China, 35; Mexico, 31; Canada, 17; Brazil, 6; other, 9	50,000
INDIUM	100		Canada, 23; China, 22; France, 11; Republic of Korea, 11; other, 33	120
MANGANESE	100		South Africa, 29; Gabon, 22; Australia, 14; Georgia, 11; other, 24	310,000
NIOBIUM	100		Brazil, 72; Canada, 18; Russia, 3; other, 7	11,300
RARE EARTHS	100		China, 78; Estonia, 6; France, 4; Japan, 4; other, 8	12,000
RUBIDIUM	100		Canada, 100	NA
SCANDIUM	100		China, 100	NA
STRONTIUM	100		Mexico, 87; Germany, 11; China, 2	17,000
TANTALUM	100		Brazil, 40; Rwanda, 26; Australia, 8; Canada, 7; other, 19	1300
VANADIUM	100		Czechia, 32; Austria, 22; Canada, 19; Republic of Korea, 18; other, 9	11,500
BISMUTH	96		China, 74; Belgium, 12; Peru, 3; other, 7	2400
URANIUM (U ₃ O ₈ equivalent) ³	93		Canada, 33; Australia, 19; Russia, 16; Kazakhstan, 11; other, 14	21,000
POTASH (K ₂ O equivalent)	92		Canada, 76; Russia, 7; Israel, 3; Chile, 2; other, 4	5,700,000
TITANIUM MINERAL CONCENTRATES (TiO ₂ content) ³	91		South Africa, 34; Australia, 26; Canada, 13; Mozambique, 10; other, 8	1,050,000
ANTIMONY	85		China, 60; Belgium, 9; Bolivia, 5; other, 11	24,000
RHENIUM	80		Chile, 69; Belgium, 3; Germany, 3; Poland, 2; other, 3	34
BARITE	>75		China, 52; India, 10; Mexico, 7; Morocco, 5; other, 1	2,220,000
BAUXITE	>75		Jamaica, 35; Brazil, 22; Guinea, 16; Guyana, 2	4,300,000
TELLURIUM	>75		Canada, 43; China, 22; Belgium, 5; Philippines, 3; other, 2	113
TIN	75		Peru, 19; Indonesia, 15; Malaysia, 15; Bolivia, 13; other, 13	32,400
COBALT	72		Norway, 12; China, 11; Japan, 8; Finland, 6; other, 35	12,100
CHROMIUM	69		South Africa, 26; Kazakhstan, 7; Russia, 4; other, 32	600,000
PLATINUM-GROUP METALS	57		South Africa, 19; Russia, 10; Italy, 5; United Kingdom, 5; other, 18	508
TITANIUM (sponge metal) ³	53		Japan, 41; China, 4; Kazakhstan, 3; Ukraine, 3; other, 2	23,000
GERMANIUM	>50		China, 31; Belgium, 12; Russia, 3; Germany, 2; other, 2	23
HAFNIUM	>50		Germany, 23; France, 16; United Kingdom, 8; China, 3	160
LITHIUM	>50		Chile, 25; Argentina, 24; China, 1	3430
TUNGSTEN	>50		China, 17; Canada, 5; Bolivia, 5; Germany, 4; other, 19	13,900
ZIRCONIUM MINERAL CONCENTRATES (ZrO ₂ content) ³	<50		South Africa, 30; Australia, 11; Senegal, 7; other, 2	28,000
ZIRCONIUM ⁴	<50		China, 34; Germany, 8; Japan, 6; other, 2	1080
MAGNESIUM METAL	<25		Israel, 7; Canada, 6; China, 3; United Kingdom, 2; other, 7	43,000
BERYLLIUM	14		Kazakhstan, 7; Japan, 2; Brazil, 1; United Kingdom, 1; other, 3	49
HELIUM (reported in million cubic meters of He) ⁴	Net exporter			21

¹Estimated. NA Not available. Source: U.S. Geological Survey, Minerals Commodity Summaries 2018 and imports are metric tons unless otherwise noted. ²In descending order of import share. May include combined data from other countries that are not listed. ³Source: U.S. Energy Information Administration, Uranium Marketing Annual Report and Domestic Uranium Production Report—Annual. (Accessed September 11, 2018, via <https://www.eia.gov/uranium/marketing/> and <https://www.eia.gov/uranium/production/annual/>). ⁴Multiple rows are shown for titanium and zirconium to reflect different material forms and import sources. ⁵The United States exports more helium than it imports. 95% of U.S. imports are from Qatar. Helium imports are in million cubic meters.

Figure 1: 2017 U.S. Net Import Reliance for Critical Minerals⁸

⁸ Adapted from U.S. Geological Survey, "Mineral Commodity Summaries 2018," 2018, <https://doi.org/10.3133/70194932>

Currently, the United States lacks domestic processing and manufacturing capabilities for some critical minerals, which results in the export of domestically produced ores and concentrates for further processing into more value-added products. Lack of domestic processing and manufacturing capabilities for critical materials makes the United States vulnerable to potential geo-economic and geo-political actions from foreign governments that may lead to price and demand volatility for specific minerals, as well as potential supply disruptions causing mineral shortfalls.

Addressing vulnerabilities in the critical minerals supply chain through an increase in domestic exploration, production, recycling, reprocessing, industry incentives, and research and development (R&D) investments would help reduce our Nation's reliance on imports, preserve our leadership in technological innovation, support job creation, and improve our national security and balance of trade. Implementing these investments and policies also enhances the technological superiority and readiness of our Armed Forces, which are among the United States' largest and most important consumers of critical minerals.⁹

To address the risk to critical mineral supply chains, President Donald J. Trump issued Executive Order 13817, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*.¹⁰ The order states, "It shall be the policy of the Federal Government to reduce the Nation's vulnerability to disruptions in the supply of critical minerals, which constitutes a strategic vulnerability for the security and prosperity of the United States. The United States will further this policy for the benefit of the American people and in a safe and environmentally responsible manner, by:

- (a) identifying new sources of critical minerals;
- (b) increasing activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and reprocessing critical minerals;

⁹ Department of Defense, "Fiscal Year 2017 Annual Industrial Capabilities Report to Congress," 2018, <https://www.businessdefense.gov/Portals/51/Documents/Resources/2017%20AIC%20RTC%2005-17-2018%20-%20Public%20Release.pdf?ver=2018-05-17-224631-340>

¹⁰ Trump, Donald J., "Presidential Executive Order on a Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," 2017, <https://www.whitehouse.gov/presidential-actions/presidential-executive-order-federal-strategy-ensure-secure-reliable-supplies-critical-minerals/>

- (c) ensuring that our miners and producers have electronic access to the most advanced topographic, geologic, and geophysical data within U.S. territory to the extent permitted by law and subject to appropriate limitations for purposes of privacy and security, including appropriate limitations to protect critical infrastructure data such as those related to national security areas; and
- (d) streamlining leasing and permitting processes to expedite exploration, production, processing, reprocessing, recycling, and domestic refining of critical minerals.”

The Executive Order directed the Secretary of the Interior, in coordination with the Secretary of Defense and other heads of relevant U.S. Government executive branch agencies, to develop a list of critical minerals. On May 18, 2018, DOI, in consultation with other Federal agencies and after review of public comments, published a list of 35 critical minerals.¹¹

The Executive Order also directed the Secretary of Commerce, in coordination with heads of selected executive branch agencies, to submit a report containing the following:

- (i) “a strategy to reduce the Nation’s reliance on critical minerals;
- (ii) an assessment of progress toward developing critical minerals recycling and reprocessing technologies, and technological alternatives to critical minerals;
- (iii) options for accessing and developing critical minerals through investment and trade with our allies and partners;
- (iv) a plan to improve the topographic, geologic, and geophysical mapping of the United States and make the resulting data and metadata electronically accessible, to the extent permitted by law and subject to appropriate limitations for purposes of privacy and security, to support private sector mineral exploration of critical minerals; and
- (v) recommendations to streamline permitting and review processes related to developing leases; enhancing access to critical mineral

¹¹ Department of the Interior, “Final List of Critical Minerals 2018,” 83 Fed. Reg. 23295; 2018, <https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018>

resources; and increasing discovery, production, and domestic refining of critical minerals.”

This document, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, is the report called for by the Executive Order. The strategy outlined in this report complements the National Security and Defense Strategies and lists specific actions Federal agencies should complete in order to ensure the Nation has access to a reliable and robust source of critical minerals to support the Nation's economic prosperity and national defense.

Approach

Increasing America's critical minerals exploration, mining, processing, and manufacturing base requires an integrated, government-wide strategy. The Department of Commerce (DOC) developed this Strategy in coordination with the Federal departments and agencies of the National Science and Technology Council's Subcommittee on Critical Minerals (CMS).¹²

The Calls to Action in this Strategy contain goals, with accompanying recommendations that describe specific actions that the Federal Government should take to meet these goals. In some recommendations, a lead agency is identified in bold font. Recommendations without an identified lead agency will be completed cooperatively between the listed agencies. Each recommendation also lists the anticipated timeframes for implementation.

This Strategy outlines a coordinated approach by the Federal Government in response to Executive Order 13817 to reduce the Nation's vulnerability to disruptions in the supply of critical minerals. An organizing principle of this strategy is to address the full supply chain of critical minerals, which spans from securement of raw materials to end-uses in both civilian and defense applications. Some Federal Government actions outlined in this strategy can be taken in the short-term, such as stockpiling and improving reliable trade options. Other actions, such as catalyzing exploration, designing and constructing new mines, and re-establishing domestic downstream manufacturing supply chains take longer to implement. In addition, the results of applied R&D efforts implemented today may take many years to fully integrate into the private sector. Overall, Federal agencies are already working towards completing many of the goals identified in this report.

The Calls to Action listed in this report support the Administration's objectives to strengthen the United States' manufacturing base and enhance U.S. industrial competitiveness. When executed, this Strategy will improve the ability of the advanced technology, industrial, and defense manufacturing sectors that use critical minerals to adapt to emerging mineral criticality issues; reduce risks for American businesses that rely on critical minerals; create a favorable U.S. business climate for production facilities at different stages of critical minerals supply chains; and

¹² The Federal departments and agencies represented on CMS are: the Central Intelligence Agency, Department of Homeland Security (DHS), DOC, Department of Defense (DOD), Department of Education (ED), Department of Energy (DOE), DOI, Department of Justice, Department of Labor (DOL), Department of State (DOS), Department of Transportation, Environmental Protection Agency (EPA), National Aeronautics and Space Administration, National Science Foundation (NSF), and U.S. Department of Agriculture (USDA).

support the economic security and national defense of the United States; all of which will reduce the Nation's vulnerability to critical mineral supply disruptions.

Calls to Action

Call to Action 1: Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains

Over the past ten years, the United States has invested in science and technology to reduce the Nation's growing dependency on foreign sources of critical minerals and foreign manufacturing supply chains. These investments primarily support three principles: diversifying sources, improving efficiency, and developing substitutes. These principles promote adaptability, resilience, and competitiveness within critical mineral supply chains. While considerable progress has been made, the United States needs an updated Federal R&D strategy and stronger support for private sector adoption of early-stage research to achieve secure and reliable supplies of critical minerals.

American ingenuity and entrepreneurship have long been a source of global leadership, economic growth, and strength in national defense. U.S. excellence in science and technology, in part, enabled U.S. dominance in minerals and mineral products in the nineteenth and twentieth centuries. Drawing upon and fostering these capabilities helps the Nation advance towards reducing disruptions in the supply of critical minerals. Accordingly, the United States has been pursuing multiple R&D investments that apply across the supply chain, including:

- diversifying domestic critical mineral sources;
- more efficiently processing, manufacturing, and recycling critical minerals to minimize waste and increase supply; and
- developing alternatives to critical minerals.

Innovations in these areas allow firms and markets to mitigate the wider potential economic and strategic harm of supply chain disruptions. Furthermore, these efforts can also help create new domestic businesses, such as recycling firms and permanent magnet start-ups; revitalize ailing industries and their communities by harnessing the value of by-products and waste streams; and increase the competitiveness of existing firms via technological spillover developed from Federal R&D, where new technologies or innovations are adapted to other industries or processes.

R&D into extracting critical minerals from a diversified set of sources could greatly increase domestic capacity. For example, many minerals are traditionally obtained from conventional sources (minerals obtained directly through mining an ore), but some can be obtained from secondary (recycled materials, post-industrial, and post-

consumer materials) and unconventional sources (minerals obtained from sources such as mine tailings, coal byproducts, extraction from seawater, and geothermal brines) as well. R&D efforts to optimize methods for extraction, concentration, separation and purification of conventional, secondary, and unconventional sources of critical minerals could increase yields and build in supply redundancy and resiliency.

All 35 critical minerals are produced from conventional mining sources; however, some minerals can also be obtained from underutilized secondary and unconventional sources. Developing a diverse set of domestic critical mineral reserves will improve domestic capacity, offset growing consumer demands, and mitigate foreign dependencies. The continual development of secondary and unconventional sources will require optimization of separation and purification methods, while also providing an opportunity to apply transformative, novel approaches. Improvements in purification and separation methods would increase yields and build in redundancy across supply chains.

The National Science and Technology Council's (NSTC) Subcommittee on Advanced Manufacturing released a strategy, *Strategy for American Leadership in Advanced Manufacturing*,¹³ that highlights the need for developing cost-effective critical minerals processing and separation technologies as well as reducing the Nation's reliance on critical materials by investigating alternative materials and developing critical mineral recycling. The recommendations and goals listed in this strategy should leverage the work being accomplished to respond to this NSTC report.

Diversifying the range of sources of critical minerals

The Federal Government has many initiatives to incentivize critical mineral development from secondary and unconventional sources. Research managed through DOE's Office of Fossil Energy and the National Energy Technology Laboratory has produced rare earth elements (REEs) from coal refuse materials and demonstrated nearly complete removal from acid mine drainage. This program supports over 30 related extramural and intramural projects with various academic institutions, industrial partners, and other national laboratories. Similarly, research by the Critical Materials Institute (CMI)—an R&D public-private partnership funded by DOE's Advanced Manufacturing Office—has produced several inventions related

¹³ Subcommittee on Advanced Manufacturing of the National Science and Technology Council, "Strategy for American Leadership in Advanced Manufacturing," October, 2018, <https://www.whitehouse.gov/wp-content/uploads/2018/10/Advanced-Manufacturing-Strategic-Plan-2018.pdf>

to REEs including one for the extraction of REEs from phosphoric acid streams¹⁴ and multiple inventions for lithium extraction from brines.¹⁵

Another source of critical minerals can be found in our oceans and in our Nation's Exclusive Economic Zone.¹⁶ Though the U.S. currently has no offshore mineral recovery activity, Pacific Northwest and Oak Ridge National Laboratories are currently developing technologies to extract minerals from seawater, including REEs, lithium, and uranium.¹⁷ In order for offshore mining to be successful, more R&D is needed to develop exploration and mining tools suitable for the cold, saline, and pressurized deep sea. In many cases, ocean-derived minerals with unique chemical properties will also require novel processes for refining and extracting high-value minerals. Countries such as Japan, Canada, and the United Kingdom have been aggressively developing and investing in their own domestic offshore mining industry and seawater extraction technologies. As of October 2018, the International Seabed Authority has issued permits for 29 contractors, none of which are U.S. companies.¹⁸

Efficient use and reuse of critical minerals

Ensuring a secure and sustainable supply of critical minerals also requires efficient use and reuse. Efficiency can be achieved in a variety of ways, including:

- content reductions in products;
- minimizing material waste during manufacturing;
- reusing postproduction waste; and
- recycling at the end of a product's life.

¹⁴ Critical Minerals Institute, "CMI Annual Report," 2017, <https://cmi.ameslab.gov/sites/default/files/cmi-annual-report-2017.pdf>

¹⁵ Department of Energy, "EERE Success Story—Geothermal Technology to Help Meet High Lithium Demand," 2016, <https://www.energy.gov/eere/success-stories/articles/eere-success-story-geothermal-technology-help-meet-high-lithium-demand>

¹⁶ The area extending no more than 200 nautical miles from the territorial sea baseline and is adjacent to the 12 nautical mile territorial sea of the United States, including the Commonwealth of Puerto Rico, Guam, American Samoa, the U.S. Virgin Islands, the Commonwealth of the Northern Mariana Islands, and any other territory or possession over which the United States exercises sovereignty.

¹⁷ S. Das et al. "Extracting Uranium from Seawater: Promising AF Series Adsorbents." Special Issue on Uranium in Seawater. *Ind. Eng. Chem. Res.*, 2016, 55 (15), pp 4110–4117. <https://pubs.acs.org/doi/abs/10.1021/acs.iecr.5b03136>

¹⁸ International Seabed Authority, "Deep Seabed Minerals Contractors," 2018, <https://www.isa.org/jm/deep-seabed-minerals-contractors>

Such improvements and innovations can also increase product cost-competitiveness. In addition, U.S. technological leadership benefits from the domestic development of innovations related to processing, manufacturing, or recycling.

Federally-supported efforts have yielded many new technologies, products, and processes. For example, a small U.S. startup licensed patents from Oak Ridge National Laboratory to recycle REEs from hard drives and to produce 3D-printed REE magnets from recycled materials. Similarly, CMI developed a new aluminum-cerium alloy that is moving towards commercialization. This new alloy is superior to existing technologies and could increase incentives to develop domestic REE deposits.

DOE, through the Vehicles Technology Office, has increased its focus on lithium-ion battery recycling to support environmental, economic, and supply chain reliability objectives. The lithium-ion battery strategy includes research to reduce the amount of cobalt needed for next-generation batteries and to economically recover components and materials from lithium-ion batteries through the ReCell Center. DOE also announced in February 2019 the Lithium-Ion Battery Recycling Prize¹⁹ – focused on optimized logistics for the domestic collection of spent batteries. Similarly, the U.S. Advanced Battery Consortium announced several contracts related to lithium-ion battery recycling, including an award that will assist a firm to implement a direct cathode-to-cathode recycling process that will decrease costs and decrease industry reliance on virgin material.

Other federally-supported efforts are increasing the reuse and recycling of various critical minerals. For example, the DOD Defense Logistics Agency Strategic Materials Division has worked with industry to reclaim nickel-based super alloys from turbine engines and germanium from infrared and night vision equipment, which has offset the requirement to purchase virgin germanium for the stockpile. The EPA's Sustainable Materials Management program is also working to refine data on U.S. waste and recycling streams, which can show where potential new sources of critical minerals can be found.²⁰

¹⁹ Department of Energy, "Energy Department Announces Battery Recycling Prize and Battery Recycling R&D Center," 2019, <https://www.energy.gov/articles/energy-department-announces-battery-recycling-prize-and-battery-recycling-rd-center>

²⁰ Environmental Protection Agency, "Advancing Sustainable Materials Management: 2016 Recycling Economic Information Report," 2016, https://www.epa.gov/sites/production/files/2017-05/documents/final_2016_rei_report.pdf

While some reuse and recycling of products containing critical minerals is occurring, minerals embedded in existing products or waste streams represent a largely untapped reservoir of potential supply due to the complexity of extracting critical minerals from an end-of-life product. Accordingly, additional research could allow industry to make full use of these resources.

Developing alternatives

Another way to minimize the Nation's growing dependency on foreign sources of critical minerals and foreign manufacturing supply chains is to use alternative minerals and components. When possible, substituting critical minerals with abundant, less-expensive replacements can conserve critical minerals, reduce vulnerability to disruptions, and lower product costs. Work supported by CMI yielded several permanent magnets (for various applications from motors to hard drives) and phosphors (for lighting) suitable for replacing current commercial products. These components contain few or no REEs and use only domestically-sourced ores and processes.²¹ Under the Advanced Research Projects Agency-Energy's Rare Earth Alternatives in Critical Technologies program, researchers at Northeastern University developed iron-nickel alloys to replace neodymium and dysprosium. Similarly, researchers at Los Alamos National Laboratory, Oak Ridge National Laboratory, and the University of Minnesota invented a permanent magnet made of iron and nitrogen in 2016. Finally, the DOE Vehicle Technologies Office funded research at Argonne National Laboratory that has contributed to commercialization of electric vehicle batteries that use cathode chemistries with less cobalt.²²

Fundamental and crosscutting R&D

Fundamental and crosscutting research provides a foundation for applied research. Fundamental research is helping to advance our understanding of the role that critical minerals play in the determination of the properties of minerals at length scales ranging from electronic interaction distances to atomic and microstructural scales. This research includes the development of novel synthesis techniques that control properties at the atomic level to develop unique capabilities for the preparation, purification, processing, and fabrication of well-characterized

²¹ Critical Minerals Institute, "CMI Success Stories," 2016,
<https://cmi.ameslab.gov/resources/success-stories>.

²² Department of Energy, "2018 Annual Merit Review Vehicle Technologies Office," 2018,
<https://www.energy.gov/eere/vehicles/downloads/2018-annual-merit-review-report>

materials. Potential fundamental research needs to include the development, validation, and application of models to theoretically and computationally identify compounds that are promising critical material substitutes.

Recent advances in computer science and programming have expanded the universe of mineral substitutes and can help accelerate movement from discovery to deployment. Current computational efforts have focused on understanding fundamental material properties. Expanding these efforts to model scarcity, toxicity, and sustainability would help improve the ability to identify new substitutes. Advanced modeling techniques can improve subsurface resource characterization by blending conventional geoscience methods with data science techniques such as machine learning, 3D visualization, and advanced data computing approaches.

Across the critical minerals supply chain, there is also a need to improve understanding of environmental health and safety issues. Protecting the environment and ensuring the health of miners and surrounding communities are crucial components of a sustainable critical minerals industry.

Goal: Develop an R&D strategy to enhance scientific and technical capabilities across critical mineral supply chains

Significant R&D needs exist across critical mineral supply chains. Coordinating these efforts among the relevant Federal agencies should ensure that resources are used efficiently and effectively. The United States needs a strategy to identify key R&D needs for source diversification; more efficient use and substitution of critical minerals; and mining, fundamental materials science, manufacturing, and environmental health and safety. The Federal Government should design this R&D strategy in coordination with existing efforts by the CMI, the various DOE applied energy research offices, the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration and Research, the National Institute of Standards and Technology (NIST), DOD, EPA, and the Nation's National Laboratories. In addition, programs like the Small Business Innovation Research program and the Small Business Technology Transfer program can create opportunities to leverage ongoing investments in R&D.

As new materials are developed through research, the Federal Government should provide support for the private sector to demonstrate, evaluate, test, and qualify these new materials for civilian and defense applications.

To achieve this goal, the following actions are recommended:

- 1.1 Develop a roadmap that identifies key R&D needs and coordinates on-going activities for source diversification, more efficient use, recycling, and substitution for critical minerals; as well as cross-cutting mining science, data

science techniques, materials science, manufacturing science and engineering, computational modeling, and environmental health and safety R&D. (*DOE, DOC [NIST, NOAA], DOD, and EPA; 2-4 years*)

- 1.2 Establish new public-private partnerships (e.g. consortia based in National Laboratories and universities) and leverage existing public-private partnerships to more efficiently address the underlying scientific and early-stage applied research challenges and enable the validation and verification of new materials and processes in key technical areas across the supply chains of critical minerals. (*DOC [NIST], DOD, and DOE; 2-4 years*)
- 1.3 Complete technical and economic feasibility studies of the production of critical minerals and related manufactured materials from secondary and unconventional sources (including coal-based resources, mine tailings, smelter slag, waste streams, end-of-life products, and seawater deposits). (*DOE, DOC (NOAA), DOD, DOI [United States Geological Survey (USGS)], and EPA; 1-2 years*)
- 1.4 Provide private industry and other external stakeholders access to computing capabilities, testing, and validation support facilities by lowering barriers to engage with government and academic laboratories, institutes, and organizations. (*DOE, DOC [NOAA], DOD, and DOI [USGS]; 2-4 years*)

Goal: Increase U.S. private industry investment in innovation and improve technology transfer from federally funded science and technology

There has been significant investment from the Federal Government and in the private sector in science and technology focused towards developing and expanding domestic capabilities for key critical mineral resource extraction, downstream processing, and manufacturing across critical mineral supply chains. Further, the U.S. has statutory authorities and programs that can facilitate and incentivize the transition of this science and technology to full scale production and integration into the U.S. industrial base.²³ For non-military related requirements in similar areas, DOE, DOI, and other agencies have supported R&D programs that could be further leveraged.

²³ Relevant DOD statutory authorities, programs, and funds include Title III of the Defense Production Act, the Strategic and Critical Materials Stock Piling Act, the Defense Manufacturing Technology Program, the Rapid Innovation Fund, and the Industrial Base Analysis and Sustainment Fund.

Existing Federal Government initiatives such as the 2018 President's Management Agenda²⁴ should be leveraged to support this goal. Specifically, the cross-agency priority goal focused on improving the transfer of federally funded R&D to the private sector.

- 1.5 Evaluate and provide recommendations to incentivize the development and use of advances in science and technology in the private industry. Options that could be considered include: (1) tax incentives for investment in new technologies, (2) government purchase programs based on the use of new technologies using domestic ores in the production of goods purchased and (3) leveraging existing DOE and DOD authorities to incentivize private sector investment in critical mineral processing and manufacturing R&D and commercialization. *(CMS, DOD, DOE, and DOI; 2-4 years)*
- 1.6 Provide support for small and medium business regarding critical mineral issues by leveraging and expanding the existing coordination between DOE's CMI, NIST's Manufacturing Extension Partnership, relevant Manufacturing USA institutes, national laboratories, and universities. Provide periodic status updates to the CMS. *(DOC [NIST], DOD, and DOE; ongoing)*

²⁴ President's Management Council and the Executive Office of the President, "President's Management Agenda," <https://www.whitehouse.gov/wp-content/uploads/2018/03/The-President%E2%80%99s-Management-Agenda.pdf>

Call to Action 2: Strengthen America's Critical Mineral Supply Chains and Defense Industrial Base

Developing robust domestic supply chains and a resilient defense industrial base for critical minerals can help sustain domestic critical mineral resource development and reduce supply risk at all stages of the supply chain, including materials processing, and manufacturing intermediate and final products. The United States needs to further encourage and incentivize U.S. private industry investment and innovation in developing, expanding, modernizing, and sustaining capabilities and industrial-scale capacity throughout the supply chain.

Executive Order 13817 identifies the need to increase activity at all levels of the critical minerals supply chain. This includes activities such as development, mining, concentration, separation, refinement, reduction, and alloying, as well as processing and manufacturing of intermediate and final products. Developing robust domestic supply chains and a resilient defense industrial base for critical minerals should help sustain domestic critical mineral resource development and reduce supply risk, while also improving U.S. industrial competitiveness, expanding production capacity, spurring job creation, and supporting U.S. economic prosperity and national defense.

The U.S. has endured a long period of decline in the domestic production of critical mineral downstream value-added material processing and associated product manufacturing, as identified in the response²⁵ to Executive Order 13806, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*. For certain critical minerals, former U.S. material producers and their downstream customers have relocated U.S. production to foreign countries such as China. Further, U.S. producers have struggled to compete with foreign producers and have experienced downsizing or business failure. For example, the REE industry has experienced downsizing, business failure, and relocation in all phases of the supply chain, including mining, separation, metal reduction, alloying and downstream manufacturing of advanced technology products such as high performance rare earth permanent magnets.

²⁵ Department of Defense, "Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States," September 2018, <https://media.defense.gov/2018/Oct/05/2002048904/-1/-1/1/ASSESSING-AND-STRENGTHENING-THE-MANUFACTURING-AND%20DEFENSE-INDUSTRIAL-BASE-AND-SUPPLY-CHAIN-RESILIENCY.PDF>

The REE industry also provides a good example of why increased activity—from R&D investments to industry incentives—is needed across the entire U.S. supply chain. Mining of ore containing REE has resumed in the U.S., which has diversified the supply of the raw material. However, the U.S. does not possess the capability to separate and process the REE concentrate and must send the concentrate to foreign facilities to perform this process. Similarly, the U.S. lacks the domestic capability to manufacture REE based high performance magnets from the separated and purified material. This results in U.S. reliance on imported magnets, which are crucial for both civilian and defense applications. Accordingly, increasing mining without increasing processing and manufacturing capabilities simply moves the source of economic and national security risk down the supply chain and creates dependence on foreign sources for these capabilities.

The U.S. needs to pursue strategies, policies, and investment that reduce our rapidly growing dependence on foreign sources of critical minerals and manufacturing supply chains while minimizing the potential vulnerability to foreign supply disruption. The U.S. should seek opportunities to expand public-private partnerships that further incentivize U.S. private industry investment; promote innovation in developing, expanding, modernizing, and sustaining domestic capabilities; enhance downstream value-added processing and associated manufacturing; and more effectively leverage the National Defense Stockpile (NDS) Program and other industrial base business assistance support programs. In addition to increasing activity, transformational R&D is needed across the entire supply chain to foster the establishment of these domestic capabilities. Therefore, actions completed under Call to Action 1, which is focused on R&D, should be leveraged and coordinated with actions completed under this Call to Action in order to increase activity across the entire critical minerals supply chain.

Goal: Understand and support the critical minerals industry and related supply chain

Critical mineral supply chain networks should be made more robust so that domestically produced critical minerals can support our Nation's economic security and national defense. The Federal Government should better understand the organization of these networks to improve the flow and competitiveness of critical minerals and their downstream supply chains.

To achieve this goal, the following actions are recommended:

- 2.1** Develop an interagency methodology to periodically assess market trends and competitiveness of the U.S. critical mineral industry and its downstream supply chains in order to recommend policies and strategies such as government investment in R&D, capacity expansion, stockpiling, and trade

actions. (*DOD, DOC [Bureau of Industry and Security (BIS)], DOE, and DOI [USGS]; 2 years*)

Goal: Leverage critical mineral expertise from stakeholders outside of the Federal Government

Federal agencies would benefit from increased collaboration with critical minerals experts from industry; academia; non-governmental and non-profit organizations; and State, local, and Tribal governments. Agencies should strive to leverage stakeholder expertise to solve complex challenges related to the critical mineral supply chain.

2.2 Establish a National Critical Minerals and Supply Chains Council through the Federal Advisory Committee Act to seek advice on the metal and non-metallic sectors of U.S. industry producers and primary processors. (*DOD, DOC, DOE, and DOI; 1-2 years*)

2.3 Convene stakeholders from across the critical mineral supply chain to:

- Identify key needs and challenges related to implementing innovations in all stages of the critical minerals supply chain, including: developing, expanding, modernizing and sustaining domestic land and offshore mining; downstream processing; associated manufacturing; and improving U.S. industrial base resiliency.
- Improve national recycling and materials recovery infrastructure to create more secure domestic supplies of critical minerals.
- Identify uses of secondary and unconventional sources of critical minerals, improve product designs that facilitate critical mineral recovery, and explore technological/R&D needs to facilitate material recovery. (*DOD, DOE, DOI [USGS], EPA; 1-3 years*)

Goal: Develop, expand, modernize, and sustain U.S. critical minerals downstream materials production capacity and supply chain resiliency

The United States continues to be increasingly dependent on foreign producers of critical minerals and as a result is vulnerable to potential supply disruptions. The U.S. faces supply chain gaps in key production capabilities and capacities. Further, many U.S. companies face significant foreign competitive pressures, declining revenue, company downsizings, production facility closures, and business failures.

As described in the response to Executive Order 13806 and to Congress,²⁶ certain U.S. critical minerals and their downstream materials processing and manufacturing capabilities and capacity represent particularly high-risks to U.S. essential civilian demands and military requirements. These risks include potential wartime shortfalls and other associated risks to the U.S. industrial base and supply chains.

- 2.4 Evaluate and provide recommendations to incentivize the U.S. private industry specific to national defense requirements, to: (1) invest in domestic capabilities and industrial-scale production of key critical mineral sources; (2) innovate in material substitution and alternative approaches to processing and recycling; and (3) support critical minerals related processing capabilities and essential productive capacity at DOD's industrial base facilities. *(DOD; ongoing)*
- 2.5 Assess different policies to stimulate increased private sector investment in: domestic industry production capabilities and capacity; investment tax credits and capital gains tax exemptions; low-interest loans and loan guarantees; workforce training funds; domestic sourcing policy; trade adjustment assistance, and small business-related procurement opportunities. *(CMS, DHS, DOD; 1 year)*
- 2.6 Assess opportunities to strengthen the use of Federal Government domestic sourcing requirements, including the Buy American Act²⁷, as a means for supporting U.S. critical mineral material resources and their domestic downstream manufacturing supply chains that are deemed essential to U.S. national defense and security. *(DOD and White House Office of Trade and Manufacturing Policy; ongoing)*

Goal: Stabilize and strengthen the NDS Program's abilities to respond rapidly to urgent and unanticipated military and essential civilian requirements during U.S. wartime and other national emergencies

The United States is heavily dependent on critical mineral imports. If China or Russia were to stop exports to the United States and its allies for a prolonged period

²⁶ Office of the Deputy Assistant Secretary of Defense for Manufacturing & Industrial Base Policy, "Fiscal Year 2017 Annual Industrial Capabilities Report to Congress," March 2018,

<https://www.businessdefense.gov/Portals/51/Documents/Resources/2017%20AIC%20RTC%2005-17-2018%20-%20Public%20Release.pdf?ver=2018-05-17-224631-340>

²⁷ Buy American Act, Pub. L. No. 72-428 (1933), codified at 41 U.S.C. §§ 8301-8305, <http://uscode.house.gov/view.xhtml?path=/prelim@title41/subtitle4/chapter83&edition=prelim>

– similar to China's rare earths embargo²⁸ in 2010—an extended supply disruption could cause significant shocks throughout U.S. and foreign critical mineral supply chains.

The NDS Program provides important protection to the United States and its domestic manufacturers from vulnerability to foreign supply disruptions. Its mission is to provide critical materials to support emergency industrial investment requirements and help address essential civilian needs during a national emergency. The Program also assesses and mitigates nationwide critical material risks to U.S. military and essential civilian requirements under near-peer wartime and other potential supply disruption scenarios.

The NDS Program is not financially sustainable following more than two decades of Congressionally-directed disbursements²⁹ of NDS Program funds to other accounts. The Program also has substantial unfunded requirements as discussed in Senate Report 115-262.³⁰

- 2.7** Investigate the use of existing DOD rapid acquisition authorities and other operating practices to increase the NDS Program's response capabilities to urgent warfighter requirements and during non-wartime national emergencies. *(DOD; ongoing)*
- 2.8** Address Congressional concerns stated in Senate Report 115-262 (Title IV, Subtitle D) regarding the lack of long-term financial stability of the NDS Transaction Fund. *(DOD; 1-2 years)*

²⁸ Keith Bradsher, "Amid Tensions, China Blocks Vital Exports to Japan," New York Times, 22 September 2010, <https://www.nytimes.com/2010/09/23/business/global/23rare.html>

²⁹ Select recipients of NDS funds include the American Battle Monuments Commission, the Defense Health Program, the Operations and Maintenance accounts of the Military Services, the Spectrum Sales program to the reclamation of previously-sold frequencies, the Foreign Military Sales Program, the Federal Hospital Insurance Trust Fund, and the Federal Supplementary Medical Insurance Trust Fund.

³⁰ United States Senate, Committee on Armed Services, "Report No. 115-262 - The John S. McCain National Defense Authorization Act for Fiscal Year 2019," page 322, June 5, 2018, <https://www.congress.gov/115/crpt/srpt262/CRPT-115srpt262.pdf>

Call to Action 3: Enhance International Trade and Cooperation Related to Critical Minerals

The United States imports many critical minerals. Maintaining access to these sources is vital for U.S. economic security and national defense. Increasing trade and cooperation with allies and partners can help reduce our Nation's reliance on sources of critical minerals that could be disrupted. Robust enforcement of U.S. trade laws and international agreements could also help address adverse impacts of market-distorting foreign trade conduct.

The United States imports many critical mineral commodities from markets around the world. Specifically, of the 35 minerals designated as critical, the United States is import-reliant (imports are greater than 50 percent of annual consumption) for 31 of these minerals, and is 100 percent reliant on imports from other countries for 14 of these 31 minerals, as demonstrated in Figure 1.

As the world economy grows, the United States will face increased competition for access to critical minerals sourced from foreign suppliers. Increasing trade with allies and partners can help reduce the likelihood of disruption to critical mineral supply chains. For example, Canada and Mexico supply all or part of U.S. consumption for many critical minerals. The United States has historical trade relationships, established logistic chains, and geographic proximity with these countries. Working with them to develop their critical mineral deposits can help improve the security of U.S. supply.

The United States cooperates with many partners around the globe on issues related to the sourcing of critical minerals. For example, the USGS has Memoranda of Understanding (MOUs) with partner countries' geological surveys to conduct research on topics of mutual interest. These MOUs have led to many joint activities, such as an ongoing dialogue on mineral information and resource assessments with Australia. The DOE has led cooperative discussions with the European Union and Japan in a trilateral R&D critical materials group for diversifying supply, developing substitutes, improving recycling, and performing criticality analyses. The USGS and the NDS Program have an ongoing relationship with U.S. allied countries to share information and best practices on critical and strategic mineral stockpiling.

Establishing and maintaining close collaboration with U.S. allies and other security partner countries to ensure national defense and economic security is also a priority for DOD. DOD has several existing authorities and mechanisms to foster

collaboration with our allies and foreign partners, which can reduce vulnerabilities to critical mineral supply disruptions, including Reciprocal Defense Procurement³¹ (RDP) agreements, Security of Supply Arrangements³² (SOSAs), and cooperation through the National Technology and Industrial Base.³³ These mechanisms are available to expedite U.S. access to ally and other security partner country suppliers. DOD is pursuing opportunities to utilize these and related forms of collaboration to reduce U.S. vulnerabilities to potential supply disruptions of critical mineral resources and their downstream supply chains.

In 2016, the U.S. Government Accountability Office issued a report³⁴ that called on Federal agencies to assess other countries' or regions' approaches to mitigating risks to critical mineral supply chains and to identify useful examples and approaches. Several Federal agencies have pursued opportunities to learn from other nations' strategies and experiences with critical mineral supply chains. For example, the USGS's effort to collect new geophysical, geological, and topographical data is modeled on Canadian and Australian investments in similar geoscience datasets. In July 2018, the geological survey authorities began discussing ways to learn from one another as well as leverage their respective minerals research investments. Similarly, EPA's Sustainable Materials Management program has hosted multiple meetings in the past several years that engaged stakeholders from the entire supply chain in conversations addressing the full life cycle of products and materials, including a G7 Alliance on Resource Efficiency workshop in March 2016.³⁵

U.S. access to critical mineral resources abroad and the viability of industries producing these minerals in the United States can be negatively impacted by trade and investment restrictions, and by foreign conduct that distorts markets through various forms of unlawful or otherwise unfair competition. U.S. trade laws and

³¹ RDP agreements are used to strengthen the defense industrial base, by among other means, allowing greater participation from friendly countries in U.S. defense procurements.

³² SOSAs can be used to prioritize acquisitions of industrial resources to meet urgent warfighter needs and critical defense requirements in participant's industrial bases.

³³ The National Technology and Industrial Base is a framework for integrating defense industrial base activities between United States, Canada, Australia, the United Kingdom of Great Britain, and Northern Ireland.

³⁴ U.S. Government Accountability Office, "Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials," September 2016, <https://www.gao.gov/products/GAO-16-699>

³⁵ Environmental Protection Agency, "U.S.-hosted Workshop on the Use of Life Cycle Concepts in Supply Chain Management to Achieve Resource Efficiency: Workshop Summary Proceedings," 2016, https://www.epa.gov/sites/production/files/2016-09/documents/g7_us_workshop_summary_proceedings_final.pdf

relevant international agreements provide tools to remedy such conduct, address the adverse impacts of such conduct on U.S. industries, and ensure U.S. national security interests are not threatened by import reliance.

Goal: Increase international exchanges with partner nations to share best practices and identify opportunities for trade and collaboration

International exchanges of information on best practices for addressing critical mineral issues would improve the ability of the United States to secure access to these minerals and reduce critical mineral market risks. The Federal Government should organize delegations composed of U.S. Government officials and private sector representatives to visit partner countries to study how they have addressed critical mineral issues. Intergovernmental agreements with partner nations are important mechanisms for ensuring continued access to critical minerals.

To achieve this goal, the following actions are recommended:

- 3.1** Continue and expand cooperation and collaboration with interested partners – particularly Canada, Australia, the European Union, Japan, and South Korea – related to: (1) critical mineral resource identification and exploration, (2) critical mineral processing and recycling, (3) mitigating supply risk and preventing supply chain disruptions, (4) R&D related to critical mineral materials and manufacturing, and (5) tracking and sharing information on foreign investment and acquisitions of mineral rights, property, and development. (*DOC [International Trade Administration (ITA)]; DOD, DOE, DOI [Bureau of Ocean Energy Management (BOEM), USGS], and DOS; ongoing*)
- 3.2** Establish accurate estimates of supply and demand of critical minerals in partner countries through consultations in conjunction with Ministerial-level forums for producers, buyers and investors. (*DOD, DOS, and DOI [BOEM, USGS]; 5 years*)
- 3.3** Complete a best practice report by evaluating other countries' approaches to private industry supply chain issues (e.g., Canadian Mining Labor Reports). (*DOD, DHS, DOC [BIS], DOE, DOI, DOL, and NSF; 2 years*)

Goal: Secure access to critical minerals through trade and investment with international partners, while ensuring that foreign trade practices do not harm U.S. industries and broader national interests

Sourcing imported critical minerals from allies and partner countries helps ensure continued access and reduces reliance on uncertain sources. Facilitating international trade with allies and partner countries could also lead to linkages that increase investment in domestic mines, mineral processing facilities, and factories.

At the same time, U.S. trade laws and international agreements provide tools to address not only restrictions that impede U.S. access to necessary mineral resources abroad, but also market-distorting foreign economic conduct that place critical mineral industries in the United States at a disadvantage.

- 3.4** Explore opportunities to utilize existing and future SOSAs, RDP agreements, and National Technology and Industrial Base collaborations to reduce U.S. vulnerability to potential supply disruptions of critical mineral materials and their downstream supply chains. *(DOD; ongoing)*
- 3.5** Monitor foreign countries' barriers to critical mineral-related trade and investment and seek to remove such barriers when they arise. *(DOC [ITA], United States Trade Representative (USTR), and DOD; ongoing)*
- 3.6** Use international trade agreements to challenge unlawful or otherwise unfair trading practices of foreign countries, where applicable. *(USTR and DOC [ITA]; ongoing)*
- 3.7** Consider whether the circumstances of U.S. reliance on imports of high risk materials merit investigations to determine the effect on U.S. national security. *(DOC [BIS] and DOD; ongoing)*

Call to Action 4: Improve Understanding of Domestic Critical Mineral Resources

Enhancing the United States' ability to identify and use domestic critical mineral resources requires advanced earth observation data products; robust mineral information collection and analysis; publication of critical mineral supply and consumption data; and critical mineral resource assessments. All data products that are developed should be made publicly available in a readily discoverable, accessible, and usable electronic format.

Identifying new sources of critical minerals requires a focused, ongoing effort to evaluate the domestic potential of conventional, secondary, and unconventional resources. The lack of geophysical, geological, topographical, and bathymetrical mapping at the scale required for mineral resource assessments and private sector exploration is a critical information gap that must be closed to facilitate domestic development. USGS data has shown that less than 18 percent of the U.S. land mass has been geologically mapped at the necessary scale, and less than five percent of the Nation has regional aeromagnetic datasets at the required resolution to perform robust mineral resource assessments. Similarly, less than 35 percent of the Nation's Exclusive Economic Zone has been bathymetrically mapped with modern methods, and even less has been geologically mapped or characterized with enough resolution to facilitate mineral assessments.³⁶

In contrast, both Australia and Canada, countries with major mining economies with similar health, safety, and environmental concerns as the United States, have developed geological and geophysical surveys and made these available to the private sector.³⁷ The availability of these national data in Australia and Canada has created a more favorable environment for private sector investment in mineral exploration and development. In the United States, improved mapping and geophysical surveys would facilitate improved critical mineral resource

³⁶ Westington, M., Varner, J., Johnson, P., Sutherland, M., Armstrong, A., & Jencks, J. 2018, "Assessing Sounding Density for a Seabed 2030 Initiative," in proceedings of the 2018 Joint Canadian Hydrographic and National Surveyors' Conference, Victoria, British Columbia, 26-29 March 2018, <https://www.eiseverywhere.com/ehome/chc-nsc2018/711593/>

³⁷ United States Senate, Committee on Energy and Natural Resources, "The United States' Increasing Dependence on Foreign Sources of Minerals and Opportunities to Rebuild and Improve the Supply Chain in the United States: Hearing Before the Senate Committee on Energy and Natural Resources," 115th Cong., 115-183, 2017, <https://www.govinfo.gov/content/pkg/CHRG-115shrg24976/pdf/CHRG-115shrg24976.pdf>

assessments and resource development, which would mitigate strategic vulnerabilities.

Federal agencies should improve the discoverability, accessibility, and usability of existing and future data. USGS is improving the discoverability of useful datasets by hosting a portal that contains a wide spectrum of minerals-related information and data including geological, geochemical, and geophysical databases; mineral assessments; ore deposit models; and more.³⁸

Data accessibility is a challenge because not all existing useful data are in electronic form. Some mineral data remain on paper or in other difficult-to-access formats; other datasets are not being maintained or updated. In a few cases, data rescue programs preserve existing paper records and increase their accessibility by converting them to digital formats. Other initiatives seek to translate different forms of information, such as images, into parameters compatible with existing datasets and models. USGS, for example, has developed the National Geological and Geophysical Data Preservation Program.³⁹ These programs and initiatives aid the interpretation of geological maps and geophysical datasets for critical mineral occurrences. In order to maximize data discoverability, accessibility, and usability, Federal data providers should use a common framework or set of standards to support data development.

For the offshore environment, BOEM and NOAA developed the Marine Cadastre, which is an integrated marine information system that provides data, tools, and technical support for offshore energy and marine planning. As discussed in Executive Order 13840, *Ocean Policy to Advance the Economic, Security, and Environmental Interests of the United States*, the Marine Cadastre will increase access to offshore mining and mapping data, which can support private sector investment.

In addition to Federal datasets, a wealth of commercial data could be leveraged through public-private partnerships that support R&D and mineral assessments. However, any such partnership would need to balance access to the data with protection of proprietary information.

³⁸ U.S. Geological Survey, "Mineral Resources Online Spatial Data," 2019, <https://mrdata.usgs.gov>

³⁹ U.S. Geological Survey, "National Geological and Geophysical Data Preservation Program," 2019, <https://datapreservation.usgs.gov/>

Goal: Use critical mineral supply and consumption data to develop metrics to enable commodity-specific mitigation strategies addressing strategic vulnerabilities

DOI, in collaboration with the CMS, developed the critical minerals list⁴⁰ using a documented methodology. The list served as the initial focus for this Strategy document. Mineral criticality is not static, but changes over time. Accordingly, the critical minerals list should be updated periodically using a transparent, documented methodology that considers changes to supply, demand, concentration of production, and current policy priorities.

Strategic vulnerabilities for minerals on the list should be mitigated in different ways, such as: development of domestic mining, trade with reliable allies and partners, substitution, recycling, or some combination of these, as identified in Executive Order 13817. The United States should evaluate potential mitigation strategies on a commodity-by-commodity basis to address the unique characteristics of each material supply chain. However, the United States requires more comprehensive data to effectively evaluate vulnerabilities over the entire material supply chain for individual mineral commodities.

USGS and the DOC's Bureau of Economic Analysis (BEA) have collaborated to evaluate the feasibility of developing natural capital accounts that could track the Nation's natural resource wealth. However, due to data limitations, the scope for developing these accounts is narrow. As a pilot effort, USGS mineral resource and industrial activity data on copper was used, with the intent that the approach could be expanded to apply to additional mineral commodities. This interagency collaboration, which includes support from Canadian and Australian subject matter experts who already use this technique, has received support from the NSF, but efforts could be expanded with better data.

To achieve this goal, the following actions are recommended:

- 4.1** Periodically update the list of critical minerals based on changes to mineral supply, demand, concentration of production, and current policy priorities. This list should be reviewed every two years and updated when necessary. Updates to the critical minerals list will inform the rest of the work being performed by agencies in this Strategy. *(DOI [USGS], CMS, DOD, and DOE; 2-4 years)*

⁴⁰ Department of the Interior, "Draft Critical Mineral List – Summary of Methodology and Background Information – U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359," 2018, <https://pubs.usgs.gov/of/2018/1021/ofr20181021.pdf>

- 4.2 Categorize and prioritize minerals on the critical minerals list to enable commodity-specific mitigation strategies. *(DOI [USGS], CMS, DOD, and DOE; 2 years)*
- 4.3 Develop a pilot effort to track indicators of the Nation's critical mineral wealth and investments in critical mineral-related economic activity. *(DOI [USGS] and DOC [BEA]; 2-4 years)*

Goal: Conduct critical mineral resource assessments and identify methods to encourage the use of secondary and unconventional sources of critical minerals

Mineral resource assessments at regional, national, and global scales are essential to understanding the Nation's critical mineral endowment in a global context. These assessments would contribute to the understanding of the geologic occurrences, spatial distribution, and characteristics of mineral deposit types that are prospective for hosting one or more critical minerals, either as primary or byproduct commodities.

When performing critical mineral resource assessments, it is important to note that some minerals are geologically coupled with primary products and can only be produced as byproducts. Gallium, for example, a critical mineral that is utilized in many domestic high technology military and civilian applications, is produced commercially as a byproduct of bauxite and zinc ore processing. Byproduct mineral production is heavily dependent on the profitability of the main resource, as byproduct minerals are typically produced in low volumes and have low economic value when compared to the main resource being mined.

- 4.4 Based on prioritization, deliver at least one national or regional domestic multi- commodity critical mineral resource assessment every two years on prospective deposit types. *(DOI [BOEM, USGS]; ongoing)*
- 4.5 Develop critical mineral resource assessment methods; characterize and map the critical mineral potential from secondary and unconventional sources; and provide a periodic status update to the CMS. *(DOI [USGS], DOE, EPA, DOS in collaboration with private sector partners; ongoing)*
- 4.6 Identify potential significant secondary and unconventional sources of critical minerals, as well as the technological developments needed to improve domestic recovery capability. Provide a periodic status update to the CMS. *(DOE, DOD, DOI [USGS], and EPA; ongoing)*
- 4.7 Recommend appropriate measures for Federal agencies to procure products that use secondary and unconventional sources of critical minerals. *(DOD and EPA; 2-4 years)*

Goal: Improve the geophysical, geological, topographical, and bathymetrical mapping of the United States and associated coastal and ocean territory

Understanding the Nation's critical minerals resources requires accurate and detailed maps. Geophysical, geological, and topographical maps can reveal possible deposits of critical minerals. Some mapping techniques, such as aeromagnetic surveys, can help users infer the presence of subsurface resources. In addition to terrestrial mapping, accurate and detailed mapping of the United States' ocean and coastal territory is needed to understand mineral potential.

- 4.8** Identify priority regions with significant critical mineral resource potential on land and in ocean regions. *(DOC [NOAA] and DOI [BOEM, USGS]; 1-2 years)*
- 4.9** Develop regional scoping studies to identify and prioritize critical mineral mapping projects based on existing datasets, the expected density of critical minerals, a mineral's level of criticality, supply chain security, mineral demand, and impacts on scientific research. *(DOC [NOAA] and DOI [BOEM, USGS]; 1-2 years)*
- 4.10** Develop and use a multi-agency protocol to assess ocean mineral resource potential in the U.S. Exclusive Economic Zone. *(DOC [NOAA], DOE [Water Power and Technology Office] and DOI [BOEM, USGS]; 2-4 years)*

Goal: Improve the discoverability, accessibility, and usability of geophysical, geological, topographical, and bathymetrical data

Many mapping datasets generated by Federal, State, Tribal, local governments, and private companies contain information pertinent to critical minerals. Improving the discoverability, accessibility, and usability of these data is challenging due to the volume and heterogeneity of relevant datasets, which are managed by a variety of Federal agencies, as well as a diverse set of user groups.

- 4.11** Continue data rescue programs to convert paper and difficult-to-access data to more usable forms, with an increased focus on records pertaining to critical minerals. Provide a periodic status update to the CMS. *(DOC [NOAA] and DOI [BOEM, USGS]; ongoing)*
- 4.12** Make geophysical, geological, geochemical, topographical, and bathymetrical survey data generated by Federal Government agencies publicly available and easily accessible in an easy-to-use electronic format through new or existing Federal data archives and dissemination portals. *(DOC [NOAA] and DOI [BOEM, USGS]; 2-4 years)*
- 4.13** Improve data discoverability, accessibility, and usability by using a common framework or set of standards to support data development and

dissemination. Best practices from existing frameworks such as the *Common Framework for Earth Observation Data*⁴¹ could be adopted to achieve this goal. (*DOI, DOC [NOAA], and DOE; 2-4 years*)

- 4.14** Increase government access to proprietary mapping datasets by building public-private partnerships. Provide a periodic status update to the CMS. (*DOI [BOEM, USGS], DOC [NOAA], DOD, DOE, and the Federal Geographic Data Committee; ongoing*)

⁴¹ Committee on Environment, Natural Resources, and Sustainability of the National Science and Technology Council, "Common Framework for Earth Observation Data," March 2016, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/common_framework_for_earth_observation_data.pdf

Call to Action 5: Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes

Critical minerals are vital for maintaining U.S. economic and national security. Accordingly, improving access to these resources is extremely important. Access includes all aspects of making minerals available for exploration and development: infrastructure to reach the mineral or mine, land-use policies (including designations), permitting reform, and economic support required to develop and maintain access over the long-term.

The United States is endowed with rich mineral deposits. Specifically, U.S. mines produced an estimated \$75.2 billion of raw mineral materials and created an estimated \$2.9 trillion in value-added products in 2017.⁴² Unfortunately, Federal permitting and land management policies have inhibited access to and the development of domestic critical minerals, which has contributed to increased reliance on foreign sources of minerals.

Each mining project is unique and may require different types of permits depending on its geologic setting, climatic conditions, and proximity to infrastructure. Navigating the complex labyrinth of local, State, Federal, and Tribal regulations for each mine is challenging, and difficulties in navigating this regulatory landscape may often lead to lengthy permitting timelines.

Mineral development can be further complicated by mixed ownership patterns that include private, Federal, State, or Tribal lands. Specifically, many lands on which economic mineral deposits are discovered may include a combination of patented mining claims (private), unpatented mining claims (Federal lands), fee lands (private), State lands, or Tribal/Alaska Native Corporation lands. In addition to the myriad of land-use designations, complications in the permitting process also arise from a complex system of statutory and administrative withdrawals from applicable mining laws including: military sites, wilderness areas, national parks, national monuments, preserves, and wildlife refuges. These withdrawals may prevent or limit mining of mineral-rich lands.

While regulatory requirements can delay the issuance of permits, mining permit applications often lack sufficient quality or key information needed for regulators to make a decision on an application. Insufficient information in the mining application can significantly delay the permitting process as it may require multiple application

⁴² U.S. Geological Survey, "Mineral Commodity Summaries 2018," 2018, <https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf>

iterations until the application is of sufficient quality to allow the permitting agencies to make a decision. Permitting decisions are then subject to various forms of appeal, protest, and litigation in State and Federal courts. All of these factors can significantly delay mine development and the mine permitting process. Accordingly, improvements to the permitting process is necessary in order to enhance access to our Nation's supply of critical minerals.

Goal: Revise the Bureau of Land Management's (BLM) and U.S. Forest Service's (USFS) land-use planning process to identify and protect access to mineral resources

BLM's resource management plans and the USFS's forest plans provide a programmatic framework for multiple use resource management and describe discretionary activities that may be authorized on lands. Federal land managers are not required to initiate a mineral resource inventory or assessment prior to the start of a land-use plan or revision. Mineral assessments for an area covered by a land-use planning document generally take two to three years to complete. In order to ensure that areas prospective for mineral development are not encumbered by a special land-use designation, the mineral inventory and assessment should be completed prior to initiation of the land-use planning process.

Increased coordination between BLM and USFS with the USGS, State and Tribal agencies, and the mining industry can help land management agencies identify the presence of minerals prior to initiating the land-use planning process, which would help reduce lengthy permitting times. For minerals that may be leased under the Mineral Leasing Act, this coordination could be accomplished through requests for information or solicitations of expression of interest to evaluate for the presence of valuable leasable minerals within the land-use planning area.

To achieve this goal, the following actions are recommended:

- 5.1** Revise land-use planning processes to require a resource inventory and assessment of minerals, including critical minerals, prior to or during the revision or creation of new land-use plans. Such an assessment should be developed with public input and any data used to inform the land-use planning process should be provided publically. *(DOI [BLM]; 2 years)*
- 5.2** Revise land-use planning processes to require that Surface Management Agencies (SMAs) designate and classify lands based on whether they are prospectively valuable for mineral development. This classification should consider the potential for the presence of or favorability for exploration and discovery of deposits of mineral resources and specifically discuss the potential for the development of critical minerals. *(DOI [BLM]; 1 year)*

- 5.3** Revise policies to ensure Federal lands identified as prospectively valuable for exploration or development of mineral resources are properly considered before they can be recommended for withdrawal or encumbered with a land-use designation that would restrict the development of these resources. *(DOI [BLM] and USDA [USFS]; 1 year)*

Goal: Complete a thorough review of withdrawals from applicable mining laws and areas restricted from mineral exploration and development on the Federal mineral estate

Many mineral resources cannot be accessed due to existing withdrawals, reservations, and other land-use restrictions. Withdrawals and reservations can serve a variety of useful purposes, including designation for wilderness, national parks, military reservations, and areas of critical environmental concern. BLM and the USFS should coordinate with the USGS, State and Tribal agencies, the mining industry, and other interested parties through requests for information or solicitations of expression of interest under the Mineral Leasing Act to evaluate withdrawn or restricted areas for the presence of minerals.

- 5.4** Review existing withdrawals, land-use designations, and planning allocations and recommend appropriate measures to reduce unnecessary impacts that they may have on mineral exploration, development, and other activities. Any analysis performed should quantify and qualify the economic and national security implications of: reducing the size of an existing withdrawal, reducing the area affected by a land-use designation, changing planning allocations, or revoking an existing withdrawal. When deciding the order in which to review existing withdrawals, restrictions, or allocations, land management agencies should prioritize consideration of areas with the greatest potential for discovery of critical minerals. *(DOI [BLM] and USDA [USFS]; 2 years)*

Goal: Review travel management plans and existing infrastructure capabilities on Federal lands for impacts to mineral exploration and development

Mining claim holders may be guaranteed reasonable access across Federal lands to their mining claims by law.⁴³ However, the term "access" is not clearly defined under existing policies and this leads to problems with the implementation of travel management plans. Travel management plans identify which roads or trails are open to motorized vehicles, off highway vehicles, and identifies areas that may be

⁴³ "The Mining Law of 1872", 30 U.S.C. §§ 22-54,
<http://uscode.house.gov/view.xhtml?path=/prelim@title30/chapter2&edition=prelim>

closed altogether and blocked from motorized use. However, these plans do not adequately account for the importance of access to lands for mineral development. Accordingly, SMA's travel management plans should be created or amended to prioritize access for mineral exploration. Further, existing infrastructure should be maintained or improved to allow access to mineral resources. Maintaining infrastructure may be the responsibility of the SMA or the private sector and depends on the purpose of the infrastructure.

- 5.5** SMAs should create or amend travel management plans to facilitate access for exploration and development of minerals to the extent practicable. When deciding the order in which to amend or create new travel management plans, land management agencies should prioritize consideration of areas that contain the greatest critical mineral potential. (*DOI [BLM] and USDA [USFS]; 1-2 years*)

Goal: Adopt a model of mineral resource development to track permitting requirements and timelines

Currently, there is no agreement between Federal and State regulatory agencies, industry, non-governmental organizations, and the Government Accountability Office on a uniform definition for time spent reviewing, processing, and issuing permits for prospecting, exploring, and developing a mine or mine site. Accordingly, land-use management and permitting agencies do not have suitable tools to analyze the performance of permitting processes.

- 5.6** Develop a publicly accessible online system to track milestones for mining projects, including the time it takes State and Federal agencies to review, process and issue permits. (*DOI [BLM] and USDA [USFS]; 1-2 years*)

Goal: Evaluate the National Environmental Policy Act (NEPA) and other regulations to provide timely processing of permit applications for mineral projects

Environmental reviews for advanced mineral exploration, development, mining and reclamation is often time consuming and can delay project development. SMAs should examine their NEPA processes and other regulations to expedite environmental reviews—without compromising environmental standards—to ensure developers of mineral projects receive a timely response to their

applications. BLM Secretarial Order 3355⁴⁴ and Revisions to NEPA Procedures⁴⁵ should be used as a starting point to improve the permitting process. However, it is important to note that any proposed regulatory revisions should continue to provide protection of Federal lands, while removing cumbersome, redundant, and unnecessary restrictions.

- 5.7** Update agency NEPA processes to streamline NEPA analysis with an emphasis on providing timely processing of mining Plans of Operations.⁴⁶ (*DOD [U.S. Army Corps of Engineers (USACE)], DOI [BLM], and USDA [USFS]; 2-4 years*)
- 5.8** Evaluate existing NEPA categorical exclusions and, if warranted, provide recommendations to create new categorical exclusions for authorizing mineral exploration and development activities that can be shown to be routine and cause no significant environmental impact. (*DOD [USACE], DOI [BLM] and USDA [USFS]; 2 years*)
- 5.9** Develop procedures that allow project proponents to participate in discussions between agency staff and NEPA contractors regarding additional requests for information. (*Council on Environmental Quality, DOI [BLM], and USDA [USFS]; 1-2 years*)
- 5.10** Revise BLM and USFS procedures to allow for the incorporation and validation of existing environmental review and analysis for mining projects completed by States and other entities. (*DOI [BLM] and USDA [USFS]; 1-2 years*)
- 5.11** Provide recommendations for revisions to 43 CFR 3809, *Surface Management*, and to 36 CFR 228 Subpart A, *Locatable Minerals*, to streamline and reduce redundant reviews. (*DOI [BLM], USDA [USFS]; 1-2 years*)
- 5.12** Harmonize regulations that affect surface mining. (*DOD [USACE], DOI [BLM], and USDA [USFS]; 1-2 years*)

⁴⁴ Bureau of Land Management, "Secretarial Order 3355, Streamlining National Environmental Policy Act Reviews and Implementation of Executive Order 13807, 'Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects,'" 2017. https://www.doi.gov/sites/doi.gov/files/uploads/3355_-_streamlining_national_environmental_policy_reviews_and_implementation.pdf

⁴⁵ U.S. Forest Service, "2018 Revisions to NEPA Procedures (36 CFR 220) and Directives," 2018, <https://www.fs.fed.us/emc/nepa/revisions/index.htm>

⁴⁶ Mining Plans of Operation are prepared by the mining company once they have determined there is an economic ore body to mine. The plan is then submitted to the SMA for review and analysis. Depending on the complexity of the project, an Environmental Assessment or Environmental Impact Statement may be required.

- 5.13** Recommend revisions to current mining regulations, including those governing locatable, salable, and leasable minerals, to reduce redundancy and streamline the permitting process. *(DOI [BLM] and USDA [USFS]; 1 year)*
- 5.14** Execute MOUs for the review of Plans of Operation for mines with mixed ownership status that includes timelines and procedures for participation and dispute resolution. *(DOI [BLM] and USDA [USFS], in coordination with State agencies; 1-2 years)*

Goal: Evaluate the Clean Water Act and the Rivers and Harbors Act to improve the permitting processing

Section 404 of the Clean Water Act requires a permit before dredged or fill material can be discharged into navigable waters or certain wetlands. Infrastructure projects—including mining operations—require such permits. On July 30, 2018, the Department of the Army, in coordination with other agencies, signed a memorandum that carries out the recommendations made by a Federal advisory committee on how the Federal Government can help states and tribes assume stream and wetlands permitting authority under the Clean Water Act.⁴⁷ This is the first step in a multi-step effort to improve the process for States and Tribes to assume authority for stream and wetland permitting under the Clean Water Act to improve water quality and accelerate job-creating economic development and infrastructure.

- 5.15** Execute Memoranda of Agreement with States and Tribes to help them assume stream and wetlands permitting authority under the Clean Water Act. *(DOD [USACE] and EPA; 1-2 years)*
- 5.16** Evaluate Sections 404 and 408 of the Clean Water Act and Sections 10 and 14 of the Rivers and Harbors Act and develop recommendations to streamline and improve the permitting process. *(DOD [USACE]; 2-4 years)*

Goal: Review regulations and consider proposing legislation to facilitate offshore critical mineral development

Offshore underwater mining from the seafloor and seawater represents an unexplored frontier in minerals production. Minerals are known to be located off the Pacific and Atlantic coasts as well as off the coast of Alaska and U.S. territories and possessions. Domestically, BOEM has authority over offshore mineral

⁴⁷ James, R.D. "Clean Water Act Section 404(g) – Non-Assumable Waters", July 30, 2018, <https://www.army.mil/e2/c/downloads/525981.pdf>

development on the Federal Outer Continental Shelf, which largely overlaps the U.S. Exclusive Economic Zone. NOAA has the primary responsibility for authorizing activities for the exploration and commercial recovery of manganese nodules by U.S. companies under the Deep Seabed Hard Mineral Resources Act.

5.17 Provide recommendations to revise existing regulations to facilitate offshore mineral leasing. (*DOC (NOAA), DOI [BOEM]; 1 year*)

5.18 Provide recommendations to improve the two-step exploration license and commercial recovery permitting process. (*DOC (NOAA), DOI [BOEM]; 1-2 years*)

Goal: Evaluate the feasibility of including high-priority mineral projects for review as part of Title 41 of the Fixing America's Surface Transportation (FAST) Act and One Federal Decision Framework

Title 41 of the FAST Act (FAST-41) and the One Federal Decision Framework were designed to improve the timeliness and predictability of the Federal environmental review and authorization for high priority infrastructure projects. These processes provide assurance that agencies will work together to develop a single permitting schedule for environmental review and authorization decisions, prepare a single environmental impact statement, sign a single record of decision, and issue all necessary authorization decisions within 90 days of issuance of the record of decision, subject to limited exceptions. Currently, mineral projects are not considered under these frameworks.

5.19 Provide recommendations to the Executive Director of the Federal Permitting Improvement Steering Council on the feasibility of allowing mineral projects to be included as part of FAST-41 and the definition of "infrastructure project" under Executive Order 13807, which established One Federal Decision framework. (*DOI [BLM], USDA [USFS]; 1 year*)

Call to Action 6: Grow the American Critical Minerals Workforce

The entire U.S. critical minerals supply chain faces workforce challenges, including aging and retiring personnel and faculty; public perceptions about the nature of mining and mineral processing; and foreign competition for U.S. talent. Unless these challenges are addressed, there may not be enough qualified U.S. workers to meet domestic production needs across the entire critical minerals supply chain.

The mineral supply chain sector workforce is currently decreasing in number as there are more retirements than graduating students. As noted in a 2013 National Academies study on emerging workforce trends in the domestic energy and mining industries, this workforce faces a wide array of challenges such as: aging and retiring workforce and faculty; a decrease in mining, mineral engineering, and economic geology programs; negative perceptions with respect to the nature of the work; and foreign competition for U.S. talent.⁴⁸

The contractions in the supply of individuals with skills in the mining industry reflect broader declines in R&D in this field. A renewed interest by the Federal Government has contributed to the initiation of programs to help address reductions in the minerals supply chain sector workforce. For example, DOE's CMI is looking to build necessary skills that have been lost in recent decades. Further, several centers of excellence at U.S. universities have been or are being established to focus on engineering challenges, including training individuals to respond more quickly to economic volatility. However, broader advances in exploration, mining, separation techniques, refining, processing, and manufacturing are still required.

The NSTC has begun to address workforce issues related to science, technology, engineering and mathematics (STEM) and outlined a five-year strategic plan in a December 2018 report, *Charting a Course for Success: America's Strategy for STEM Education*.⁴⁹ Similarly, the NSTC's Subcommittee on Advanced Manufacturing released a 2018 report, *Strategy for American Leadership in Advanced*

⁴⁸ National Research Council, "Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action, National Academies," pages 83-85, 2013, <https://www.nap.edu/catalog/18250/emerging-workforce-trends-in-the-us-energy-and-mining-industries>

⁴⁹ Committee on STEM Education of the National Science and Technology Council, "Charting a Course for Success: America's Strategy for STEM Education," December 2018, <https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf>

Manufacturing,⁵⁰ which highlighted the need to educate, train, and connect the manufacturing workforce. Many of the goals and recommendations listed below should leverage existing Federal initiatives, such as the STEM and advanced manufacturing reports to help bolster the minerals supply chain sector workforce.

Goal: Bolster education in mining engineering, geology, and other fields related to critical minerals mining and manufacturing

Joint support for innovation in mining techniques and technology by Government, academia, and industry partners could improve the industry as well as graduate and undergraduate education. Fostering university faculty and departments involved in cutting-edge research to contribute new knowledge could enhance the quality of higher education and ensure the ability of universities to meet future demand for mineral supply chain sector engineers after impending faculty retirements. Community and technical colleges could also promote relevant education and training efforts.

To achieve this goal, the following actions are recommended:

- 6.1** Develop partnerships with academia and the private sector to support universities involved with mineral-related research and courses to enhance the quality of higher education. Provide periodic status updates to the CMS. (*DOC [NOAA], DOD, DOE [DOE National Laboratories], DOI [USGS], ED, and NSF; ongoing*)
- 6.2** Evaluate opportunities to facilitate partnerships between industry, community colleges, and technical colleges to coordinate necessary credentialing/skillset alignment, with special attention to the regional nature of extractive industries and critical minerals. Provide periodic status updates to the CMS. (*DOI and ED; ongoing*)
- 6.3** Bolster the mineral supply chain sector workforce by leveraging provisions in the Strengthening Career and Technical Education for the 21st Century Act.⁵¹ (*ED; 2-4 years*)

⁵⁰ Subcommittee on Advanced Manufacturing of the National Science and Technology Council, "Strategy for American Leadership in Advanced Manufacturing," October, 2018, <https://www.whitehouse.gov/wp-content/uploads/2018/10/Advanced-Manufacturing-Strategic-Plan-2018.pdf>

⁵¹ United States Congress, "Strengthening Career and Technical Education for the 21st Century Act," Pub. L. No. 115-224, 132 Stat. 1564, <https://www.congress.gov/115/bills/hr2353/BILLS-115hr2353enr.pdf>

Goal: Promote interdisciplinary collaboration among material science, computer science, and related disciplines to modernize the minerals supply sector industry and make the field more attractive to new talent

Traditional mining engineering programs have had trouble attracting students. Interdisciplinary collaboration among fields such as material science, computer science, and other disciplines could attract top talent while modernizing the industry. Interdisciplinary programs are an important step to train individuals with the skills necessary to staff modern 21st century mining operations, including autonomous heavy equipment, drones, process automation, and bio-mediated refining processes and controls.

- 6.4** Foster collaboration among fields such as material science, computer science, and other disciplines to attract top talent while modernizing the industry. Provide periodic status updates to the CMS. (*DOC [NOAA], DOD, DOE, ED, and NSF; 2-4 years*)

Goal: Implement personnel and management reform to ensure appropriate human capital to support exploration and development of critical minerals on Federal lands

BLM and USFS have major challenges in recruiting and retaining a trained workforce to support critical mineral programs (e.g., biologists, archaeologists, geologists, and engineers). These challenges cause delays and bottlenecks in permitting mining projects. Undertaking personnel and management reform could help improve the efficiency of BLM and USFS.

- 6.5** Develop policies and training to ensure appropriate managers and staff at DOI and USDA recognize the importance and high national priority of critical mineral exploration and development. (*DOI [BLM] and USDA [USFS]; 2-3 years*)
- 6.6** Examine and consider an increase in field staff expert positions, including the National Mineral Examination Team and Certified Mineral Examiner programs. Finalize BLM and USFS Mining Law Administration MOU to facilitate staffing across agencies. (*DOI [BLM] and USDA [USFS]; 1-2 years*)

Goal: Facilitate sustained interaction with critical mineral stakeholders and the general public

The Federal Government and critical mineral stakeholders need to effectively communicate the importance of critical minerals to the general public. Options such as public service announcements, social media, educational curricula, interpretive displays, online products, and presentations at public fora could be used.

- 6.7** Develop effective outreach efforts to the general public to convey the importance of critical minerals to the U.S. economy and national security by working with academia and educational partners. *(CMS, DOE, and DOI [BLM, BOEM, USGS]; ongoing)*

Next Steps

This Strategy identifies a number of goals and recommended actions Federal departments and agencies can pursue to improve the availability of critical minerals and their downstream supply chains in the United States, reducing the Nation's vulnerability to supply disruptions. In order for the Strategy to be successful, agencies should coordinate and dedicate resources to accomplish each goal.

Given the dynamic, crosscutting nature of critical minerals issues, pursuing the goals and recommendations in this Strategy demands adaptive, coordinated efforts across the Federal Government. This requires ongoing analysis and stakeholder outreach activities that monitors changing conditions and synthesizes information across a range of topics, including critical minerals R&D, production, trade, consumption, and recycling. Such activities provide the capacity for the U.S. Government to continuously adapt by identifying emerging issues, prioritizing responses, and assessing progress.

The CMS is the interagency coordinating body for critical minerals. As part of their work, the CMS should be the entity that coordinates implementation of this Strategy. Overall, the Strategy should be evaluated 5 years after issuance to determine the efficacy of the recommendations and to determine the relevance of the recommendations given current priorities and challenges the U.S. Government is facing. Further, the CMS should adaptively coordinate the implementation of this Strategy to reflect emerging critical mineral priorities and challenges.

The list of Critical Minerals published by DOI in May 2018 in response to Executive Order 13817 is also an important part of this Strategy. Accordingly, DOI, in coordination with the CMS, should evaluate the list of critical minerals biennially based on changes to mineral supply, demand, concentration of production, and current policy priorities. Based on this evaluation, the list should be updated if necessary, which should in turn inform adjustments to the implementation of this Strategy.

Conclusion

Minerals are the raw materials needed to build many products used by Americans in everyday life, such as cell phones, computers, automobiles, and airplanes. The United States is heavily dependent on foreign sources of many minerals and on foreign supply chains that build value-added products, resulting in the potential for strategic vulnerabilities to our Nation's economic prosperity and national security. Accordingly, President Donald J. Trump issued Executive Order 13817, which seeks to address these vulnerabilities and tasked the Department of the Interior, in coordination with other Federal agencies, to develop a list of minerals deemed critical, and the Department of Commerce, in coordination with other Federal agencies, to develop a strategy to reduce the Nation's vulnerability to disruptions in the supply of critical minerals.

The Department of the Interior published a list of 35 critical minerals in May 2018. This report, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, is the strategy requested by the Executive Order. It is a comprehensive interagency strategy that seeks to address vulnerabilities within the full critical minerals supply chain, which spans from securement of raw materials to end-uses in both civilian and defense applications. Specifically, this Strategy identifies 24 goals and 61 recommendations that will:

- help identify new sources of critical minerals;
- enhance activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and reprocessing;
- seek to stimulate private sector investment and growth of domestic downstream value-added processing and manufacturing;
- ensure that miners, producers, and land managers have access to the most advanced mapping data; and
- outline a path to streamline leasing and permitting processes in a safe and environmentally responsible manner.

Given the crosscutting nature of critical minerals issues, pursuing the goals and recommendations in this Strategy demands adaptive, coordinated efforts across the Federal Government. Accordingly, this Strategy should be periodically evaluated to determine the efficacy and relevance of the recommendations given current U.S. Government priorities and challenges.

Abbreviations

BEA	Bureau of Economic Analysis
BIS	Bureau of Industry and Security
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
CMI	Critical Materials Institute
CMS	Subcommittee on Critical Minerals
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOL	Department of Labor
DOS	Department of State
ED	Department of Education
EPA	Environmental Protection Agency
FAST	Fixing America's Surface Transportation Act
ITA	International Trade Administration
MOUs	Memoranda of Understanding
NDS	National Defense Stockpile
NEPA	National Environmental Policy Act
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSTC	National Science and Technology Council
R&D	Research and Development
REE	rare earth elements
RDP	Reciprocal Defense Procurement
SMA	Surface Management Agencies
SOSA	Security of Supply Arrangement
STEM	science, technology, engineering and mathematics
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
USTR	United States Trade Representative

**DEPUTY MINISTER ROUNDTABLE ON CRITICAL MINERALS
AND A CANADA-US JOINT ACTION PLAN**

August 7, 2019, 15:00 - 16:00

Main boardroom, 21st floor, 580 Booth Street, Ottawa

613-960-7513 or 1877-413-4788 / Conf. ID: 

MEETING AGENDA

1. **Welcome and Introductions (3 minutes)**
Shawn Tupper, Associate Deputy Minister of Natural Resources
2. **Critical Minerals: Global trends and the North American context (7 minutes)**
Glenn Mason, Assistant Deputy Minister, Lands and Minerals Sector
Jay Khosla, Assistant Deputy Minister, Energy Sector
3. **Canada-US Relations and a Joint Action Plan on Critical Minerals (5 minutes)**
Shawn Tupper, Associate Deputy Minister of Natural Resources
David MacNaughton, Ambassador of Canada to the United States and/or Kirsten Hillman,
Deputy Ambassador to the United States
4. **Roundtable Discussion (40 minutes)**
5. **Closing Remarks (5 minutes)**
Shawn Tupper, Associate Deputy Minister of Natural Resources



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Annex 4



CRITICAL MINERALS

CANADA'S ROLE IN SECURING THE NORTH AMERICAN VALUE CHAIN

Canada



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THE GLOBAL ECONOMY IS INCREASINGLY DEPENDENT ON MINERAL INPUTS



Defence and Security Technologies



Consumer Electronics



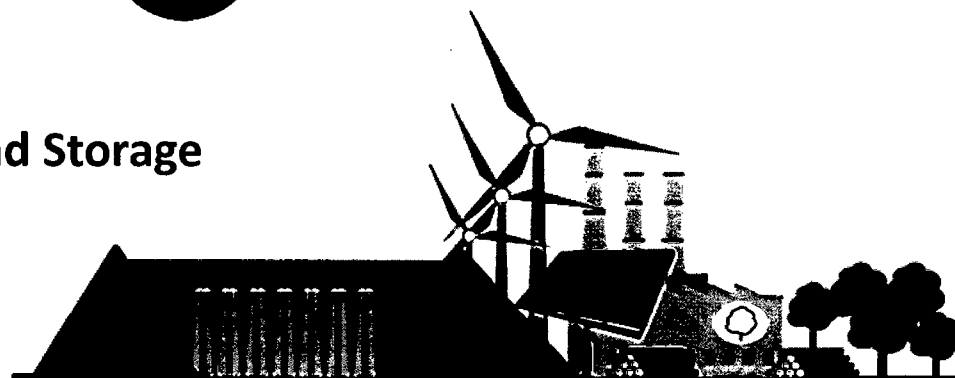
Electric Vehicle Batteries



Critical Infrastructure



Renewable Energy Production and Storage





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LEADING ECONOMIES ARE TAKING ACTION TO SECURE CRITICAL MINERAL SUPPLIES



UNITED STATES

The **US Critical Minerals Strategy** focuses on securing access to responsible and sustainable supplies of critical minerals to fuel the low carbon transition.



EUROPEAN UNION

The **EU Raw Materials Strategy** focuses on securing access to responsible and sustainable critical minerals to fuel the low carbon transition.



JAPAN & KOREA



Both nations are seeking to **minimize their import dependence** by **diversifying supply**. State-owned enterprises JOGMEC and KORES are aggressively seeking new global supplies.



AUSTRALIA

Australia's **critical mineral strategy** focuses on promoting investment in processing, innovation incentives and infrastructure.



CHINA

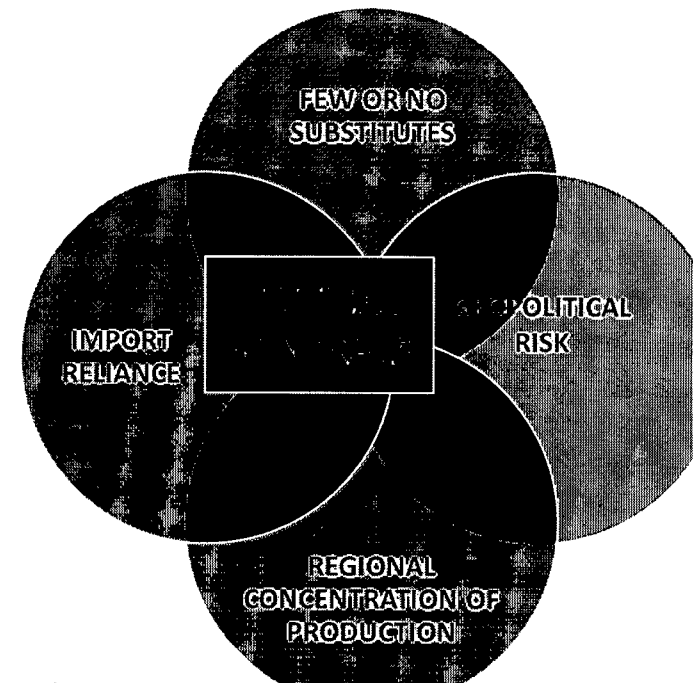
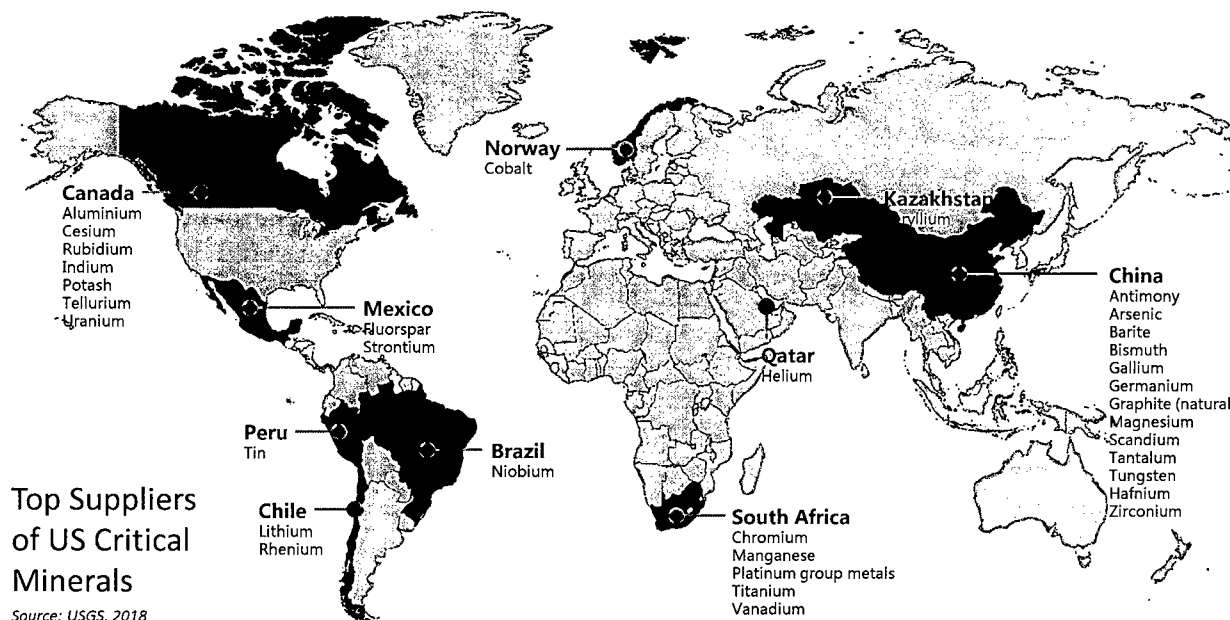
For decades, China has pursued a strategy to control global critical mineral production and processing. This strategy has led to China being the leading producer of minerals vital to the modern economy, including:

Lithium	59%
Graphite	70%
Cobalt	36%
Gallium	95%
Vanadium	56%
Rare Earth Elements	80%



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CRITICAL MINERALS REPRESENT RISKS TO GLOBAL SUPPLY CHAINS



There is no global dependency on critical minerals. Critical minerals are country-specific and their 'criticality' can change based on supply and demand



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CANADA AND THE UNITED STATES ARE DEVELOPING A JOINT ACTION PLAN ON CRITICAL MINERALS COLLABORATION

On June 20, 2019, Prime Minister Trudeau and President Trump announced their intent to develop a Joint Action Plan on Critical Minerals Collaboration

A Joint Action Plan will complement the US Federal Critical Minerals Strategy and the Canadian Minerals and Metals Plan

Possible areas of collaboration include:

- Increased R&D and information sharing
- Enhanced critical minerals supply chains
- Stronger defense industrial base
- Enhanced international trade and cooperation





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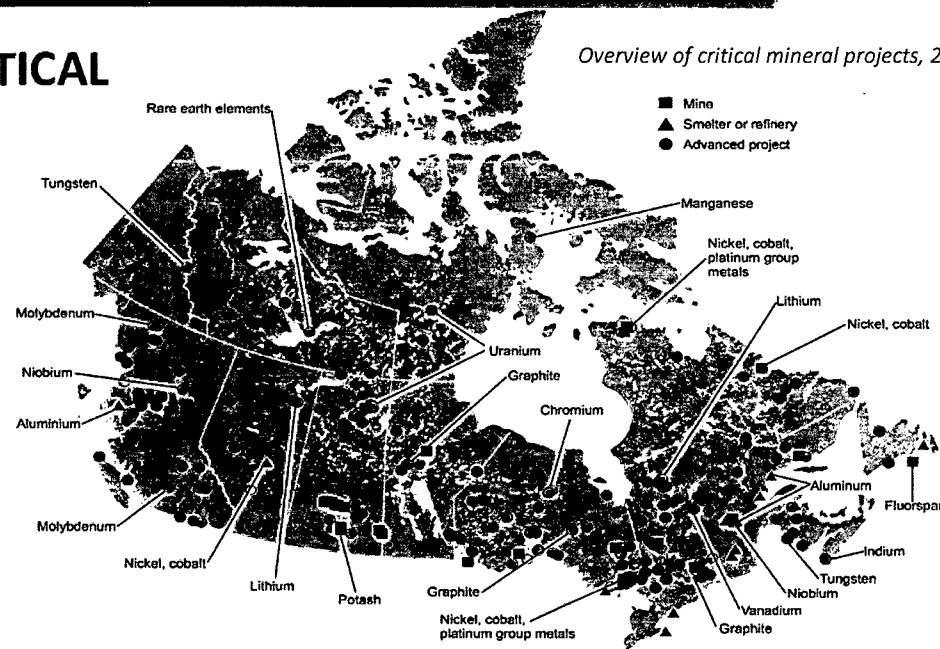
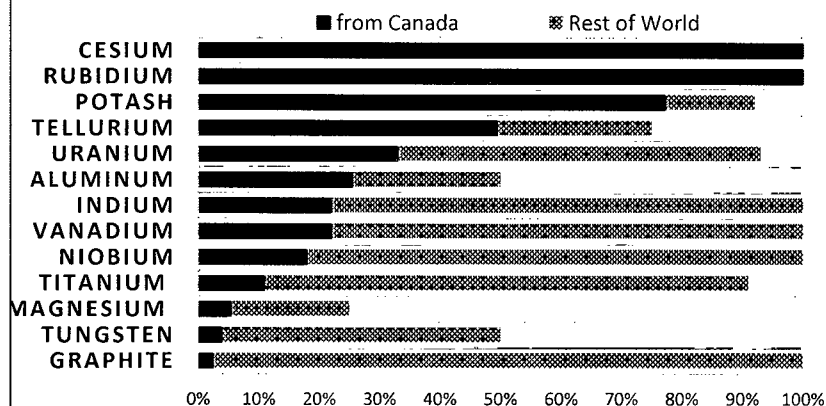
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CANADA IS AN IMPORTANT SOURCE OF CRITICAL MINERAL SUPPLY AND HAS POTENTIAL TO INCREASE & DIVERSIFY PRODUCTION



Canada is a leading supplier for 13 of the 35 US critical minerals**
Including Uranium, potash, niobium, and graphite

U.S. Import Reliance of Selected Critical Minerals



Overview of critical mineral projects, 2019, NRCan

- ✓ Rare earths: 16 advanced projects and potentially 1 of the top 5 countries in the world
- ✓ Uranium: 2nd largest producer with highest grade supplies in the world
- ✓ Cobalt and nickel: world leading producer and 70 advanced stage projects
- ✓ Graphite: 4th in global production and 14 advanced stage projects
- ✓ Lithium: 17 advanced and near production stage projects
- ✓ Potash: World's leading supplier and largest reserves



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AN OPPORTUNITY TO BUILD CANADIAN VALUE CHAINS

Collaboration on critical minerals with the United States represents opportunities not only to **attract investment into Canadian exploration and mining projects**, but also to **foster Canadian value chains** for:

- Defence
- Electric vehicles and batteries
- Small modular reactors
- Energy storage technologies
- Clean and advanced technologies
- Advanced manufacturing and materials
- Renewables

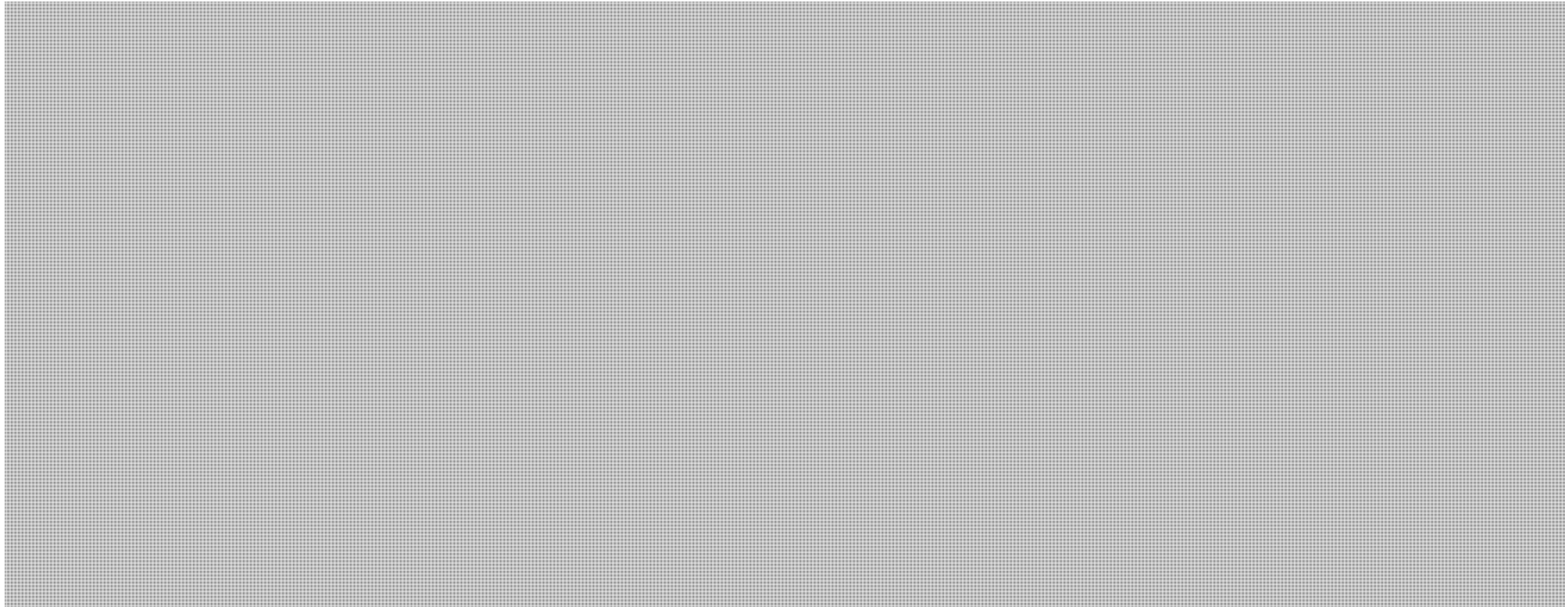
A focus on building Canadian critical minerals value chains presents a **real opportunity for job creation and economic growth across Canada and across industry sectors.**





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Draft Critical Mineral List—Summary of Methodology and Background Information—U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359

Open-File Report 2018–1021

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

Draft Critical Mineral List—Summary of Methodology and Background Information—U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359

By Steven M. Fortier, Nedal T. Nassar, Graham W. Lederer, Jamie Brainard,
Joseph Gambogi, Erin A. McCullough

Open-File Report 2018–1021

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

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Deputy Director
exercising the authority of the Director

U.S. Geological Survey, Reston, Virginia: 2018

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Draft Critical Mineral List—Summary of Methodology and Background Information—U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359

By Steven M. Fortier, Nedal T. Nassar, Graham W. Lederer, Jamie Brainard, Joseph Gambogi,
Erin A. McCullough

Statement of Issue

Pursuant to the Presidential Executive Order (EO) No. 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," the Secretary of the Interior, in coordination with the Secretary of Defense, and in consultation with the heads of other relevant executive departments and agencies, was tasked with developing and submitting a draft list of minerals defined as "critical minerals" to the Federal Register within 60 days of the issue of the EO (December 20, 2017; Executive Office of the President, 2017). U.S. Department of the Interior (DOI) Secretarial Order (SO) No. 3359, "Critical Mineral Independence and Security," tasked the Director of the U.S. Geological Survey (USGS), in coordination with the Bureau of Land Management (BLM), with developing and submitting a proposed draft list of minerals defined as "critical minerals" within 30 days of the issue of the SO (U.S. Department of the Interior, 2017). USGS and BLM developed the unranked draft list presented herein in cooperation with the U.S. Departments of Defense (DOD), Energy, State, and Commerce, and other members of the National Science and Technology Council Subcommittee on Critical and Strategic Mineral Supply Chains (CSMSC).

Summary of the Proposed Draft List

Based on an analysis using multiple criteria explained below, 35 minerals or mineral material groups have been identified that are currently (February 2018) considered critical. These include the following: aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluor spar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium. The

categorization of minerals as critical may change during the course of the review process and is thus provisional.

Definition

A "critical mineral," as defined by EO No. 13817, is a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security. Disruptions in supply chains may arise for any number of reasons, including natural disasters, labor strife, trade disputes, resource nationalism, conflict, and so on. The draft list provided herein is based on the definition of a "critical material" provided in the EO. The U.S. Government and other organizations have other definitions and rely on other criteria to identify a material or mineral as "critical" or otherwise important. This draft list is not intended to replace related terms and definitions of materials that are deemed strategic, critical, or otherwise important (for example, the National Defense Stockpile).

Introduction

Lists of critical minerals, although useful to identify and prioritize materials of concern, are, by necessity, a simplification of a complex issue; there is no one method that will meet the needs of all interested parties. A number of factors are relevant when using such information. First, what constitutes a critical mineral depends, in some respects, on who is asking the question. A company producing hydrocarbons, for example, may have a very different idea of what materials

2 Draft Critical Mineral List—Summary of Methodology and Background Information

are critical than an electronics manufacturer or the DOD. The USGS tracks nonfuel mineral information on a continuous and annual basis, in part, to monitor the criticality and import dependence of critical minerals. The U.S. Energy Information Administration tracks uranium mineral information in a similar way. The USGS also completes geologic mapping, mineral resource assessments, and basic research that allow the distribution of critical minerals to be identified and understood. Without this background information, it is not possible to fully understand the criticality and security of the Nation's mineral supply. Specifically, various agencies, including the DOI, DOD, U.S. Department of Commerce, U.S. Department of Energy, U.S. Department of Agriculture, and the United States Trade Representative, would be expected to prioritize specific minerals in the draft list presented herein differently based on the importance to their missions.

Previous work in this field has resulted in several methodologies and produced a variety of lists of critical minerals particularly during the decade after the seminal work of the National Academy of Sciences in 2008 (National Research Council, 2008). All such studies differed somewhat in the approach taken and the resulting lists that were produced; a review of these studies is beyond the scope of this document. For the purposes of meeting the objectives of the above referenced EO and SO, the approach described in the next paragraph was used to generate the draft list proposed herein.

The critical mineral early warning screening methodology developed by the CSMSC in 2016 (U.S. National Science and Technology Council, 2016), and updated in 2017 (McCullough and Nassar, 2017), served as the starting point for the development of the draft list. The screening methodology was designed to identify and prioritize minerals or mineral materials for in depth study to evaluate risks to security of supply. The screening methodology is global in scope and did not specifically address U.S. import reliance. It only addressed nonfuel minerals and, thus, did not include uranium. One of the principle metrics used in the CSMSC screening methodology was the Herfindahl-Hirschman index (HHI). The HHI is used by the Department of Justice and the Federal Trade Commission to identify highly concentrated markets when a company may control market share above an established threshold of 2,500 on a dimensionless scale that ranges from 0 to 10,000. Additional tools and sources of information used to produce the draft list, make it U.S. specific, and that include consideration of uranium were as follows: (1) U.S. net import reliance (NIR) statistics as published annually in the USGS Mineral Commodity Summaries (U.S. Geological Survey, variously dated); (2) USGS Professional Paper 1802 "Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply" (Schulz and others, 2017); (3) various inputs from the DOD; (4) the National Defense Authorization Act for fiscal year 2018 (H.R. 2810); (5) U.S. Energy Information Administration uranium statistics in the "2016 Uranium Marketing Annual

Report" (U.S. Energy Information Administration, 2017); and (6) the judgment of subject-matter experts of the USGS, and other U.S. Government agencies including representatives of other DOI Bureaus and members of the CSMSC Subcommittee. Additional information and references on these tools and sources are provided in appendix 1.

The draft list resulting from the application of these metrics is shown in table 1 with materials listed in alphabetical order. Most of entries in the table are materials for which production concentration and net import reliance are high (typically HHI greater than 2,500 and NIR greater than 50 percent for either the years 2016, 2017, or both). Entries that are below the chosen threshold based on one metric or the other, but for which a case for inclusion can be made on grounds of particularly critical applications, also are included. The latter is based on the judgment of subject-matter experts of the CSMSC Subcommittee. The countries that are the largest producers and largest U.S. suppliers are listed adjacent to the respective metrics for those categories. As an example, China dominates the production of antimony and is the largest import source to the United States. It should be noted that import reliance is not the same as import vulnerability (defined as a material with high NIR that is sourced from a country or countries with high governance risk). Many of the countries identified as the largest source of U.S. imports also have relatively high governance risks. Key end use sector data also are shown in a matrix format indicative of the industrial sectors in which a particular material finds important end uses. Finally, notable examples of end use applications are given for each listed material. A more detailed view of the industrial sectors and key technologies for which the listed commodities find important end uses is provided in table 2. A brief summary of information relevant to the criticality for each listed material is included in appendix 2.

A supply chain approach was used for some of the materials on the draft list, consistent with the definition of a critical mineral in the EO. For example, aluminum is included to represent the aluminum supply chain because the United States is 100 percent reliant on imports of metallurgical grade bauxite, and some forms of high purity alumina and aluminum metal used for important applications also are considered critical. Likewise, several important ferroalloys used to manufacture specialty steels and superalloys are not listed individually; instead, they are included by inference in the supply chain of the material alloyed with iron. Ferroniobium, for example, is captured by the presence of niobium on the draft list in recognition that niobium is part of the ferroniobium supply chain. It should be noted that potential supply chain vulnerabilities relating to critical minerals extend beyond what is described herein and should be considered as part of the strategy within the report to the President required by the EO. For example, enhancing domestic mineral processing capability is important to prevent the immediate export of domestically mined ore.

Table 1. Draft list of critical minerals.

[X, applicable sector; --, not applicable]

Mineral commodity	Sectors						Top producer	Top supplier	Notable example application
	Aerospace (nondefense)	Defense	Energy	Telecommunications and electronics	Transportation (nonaerospace)	Other			
Aluminum	X	X	X	X	X	X	China	Canada	Aircraft, power transmission lines, lightweight alloys.
Antimony	--	X	X	X	X	X	China	China	Lead-acid batteries.
Arsenic	--	X	X	X	--	X	China	China	Microwave communications (gallium arsenide).
Barite	--	--	X	X	--	X	China	China	Oil and gas drilling fluid.
Beryllium	X	X	X	X	--	X	United States	Kazakhstan	Satellite communications, beryllium metal for aerospace.
Bismuth	--	X	X	X	--	X	China	China	Pharmaceuticals, lead-free solders.
Cesium and rubidium	X	X	X	X	--	X	Canada	Canada	Medical applications, global positioning satellites, night-vision devices.
Chromium	X	X	X	X	X	X	South Africa	South Africa	Jet engines (superalloys), stainless steels.
Cobalt	X	X	X	X	X	X	Congo ¹ (Kinshasa)	Norway	Jet engines (superalloys), rechargeable batteries.
Fluorspar	--	--	X	X	--	X	China	Mexico	Aluminum and steel production, uranium processing.
Gallium	X	X	X	X	--	X	China	China	Radar, light-emitting diodes (LEDs), cellular phones.
Germanium	X	X	X	X	--	X	China	China	Infrared devices, fiber optics.
Graphite (natural)	X	X	X	X	X	X	China	China	Rechargeable batteries, body armor.
Helium	--	--	--	X	--	X	United States	Qatar	Cryogenic (magnetic resonance imaging [MRI]).
Indium	X	X	X	X	--	X	China	Canada	Flat-panel displays (indium-tin-oxide), specialty alloys.
Lithium	X	X	X	X	X	X	Australia	Chile	Rechargeable batteries, aluminum-lithium alloys for aerospace.
Magnesium	X	X	X	X	X	X	China	China	Incendiary countermeasures for aerospace.
Manganese	X	X	X	X	X	X	China	South Africa	Aluminum and steel production, lightweight alloys.
Niobium	X	X	X	X	--	X	Brazil	Brazil	High-strength steel for defense and infrastructure.
Platinum group metals ²	X	--	X	X	X	X	South Africa	South Africa	Catalysts, superalloys for jet engines.
Potash	--	--	X	X	--	X	Canada	Canada	Agricultural fertilizer.
Rare earth elements ³	X	X	X	X	X	X	China	China	Aerospace guidance, lasers, fiber optics.
Rhenium	X	--	X	X	--	X	Chile	Chile	Jet engines (superalloys), catalysts.
Scandium	X	X	X	X	--	X	China	China	Lightweight alloys, fuel cells.
Strontium	X	X	X	X	X	X	Spain	Mexico	Aluminum alloys, permanent magnets, flares.
Tantalum	X	X	X	X	--	X	Rwanda	China	Capacitors in cellular phones, jet engines (superalloys).
Tellurium	--	X	X	X	--	X	China	Canada	Infrared devices (night vision), solar cells.
Tin	--	X	--	X	--	X	China	Peru	Solder, flat-panel displays (indium-tin-oxide).
Titanium	X	X	X	X	--	X	China	South Africa	Jet engines (superalloys) and airframes (titanium alloys), armor.
Tungsten	X	X	X	X	--	X	China	China	Cutting and drilling tools, catalysts, jet engines (superalloys).
Uranium	X	X	X	--	--	X	Kazakhstan	Canada	Nuclear applications, medical applications.
Vanadium	X	X	X	X	--	X	China	South Africa	Jet engines (superalloys) and airframes (titanium alloys), high-strength steel.
Zirconium and hafnium	X	X	X	X	--	X	Australia	China	Thermal barrier coating in jet engines, nuclear applications.

¹Democratic Republic of the Congo.²This category includes platinum, palladium, rhodium, ruthenium, iridium, and osmium.³This category includes yttrium and the lanthanides.

4 Draft Critical Mineral List—Summary of Methodology and Background Information

Table 2. Important technologies and applications by mineral commodity and industrial sector.

[NA, not applicable; SOFC, solid oxide fuel cell; PEM, polymer electrolyte membrane]

Mineral commodity	Aerospace (nondefense)	Defense	Energy	Telecommunications and electronics	Transportation (nonaerospace)	Other
Aluminum	• Airframes • Fuselage	• Aerospace • Naval vessels • Ground vehicles	• Power transmission lines • Lightweight alloys • Land based turbines (superalloys, coating) • Aluminum oxide catalyst supports	NA	• Marine vessels • Ground vehicles • Lightweight alloys	• Infrastructure • Packaging • Aluminum oxide refractories
Antimony	NA	• Lead-acid batteries • Infrared devices (night vision)	• Lead-acid batteries	• Semiconductors	• Lead-acid batteries	• Flame-retardant materials • Glass and ceramics manufacturing • Plastics manufacturing
Arsenic	NA	• Semiconductors	• Solar cells	• Cellular phones	NA	• Gallium arsenide integrated circuits • Optoelectronic devices
Barite	NA	NA	• Oil and gas drilling fluid	NA	NA	• Radiation shielding • Medical applications
Beryllium	• Structural and optical components • Aluminum alloys	• Guidance systems • Radar	• Oil and gas drilling equipment • Nuclear applications	• Undersea cable housings • Contacts	NA	• X-ray windows
Bismuth	NA	• Thermoelectric devices • Machining alloys	• Bismuth oxide soft applications	• Solder • Semiconductor manufacturing	NA	• Pharmaceutical • Glass and ceramics manufacturing • Metallurgical applications
Cesium and rubidium	• Global positioning satellites • Guidance systems	• Infrared devices (night vision)	• Fuel cells • Solar cells	• Cellular phones • Motion sensor devices • Fiber optics • Photoelectric cells	NA	• Medical applications • Scintillation • Atomic clocks • Specialty glass
Chromium	• Jet engines (superalloys)	• Superalloys • Specialty steels	• Land-based turbines • SOFC applications	NA	NA	• Stainless steel • Specialty steels • Corrosion resistance
Cobalt	• Jet engines (superalloys) • Rechargeable batteries	• Superalloys • Permanent magnets • Rechargeable batteries	• Rechargeable batteries • Petroleum catalysts • Land-based turbines • Superalloys • SOFC catalysts • High temperature boiler tubing	• Rechargeable batteries	• Rechargeable batteries	• Cemented carbides • Specialty steels

Table 2. Important technologies and applications by mineral commodity and industrial sector.—Continued

[NA, not applicable; SOFC, solid oxide fuel cell; PEM, polymer electrolyte membrane]

Mineral commodity	Aerospace (nondefense)	Defense	Energy	Telecommunications and electronics	Transportation (nonaerospace)	Other
Fluorspar	NA	NA	• Uranium processing	• Semiconductor manufacturing	NA	• Hydrofluoric acid • Steelmaking • Aluminum production • Metallurgical applications • Fluorochemicals
Gallium	• Solar cells in satellites • Microwave power transistors	• Radar • Radio frequency amplifiers • Infrared imaging	• Solar cells • Light-emitting diodes	• Cellular phones • Light-emitting diodes • Integrated circuits	NA	• Optoelectronic devices • Lasers • Photodetectors
Germanium	• Solar cells in satellites	• Infrared devices (night-vision) • Guidance systems	• Solar cells	• Fiber optics • Integrated circuits	NA	• Optoelectronic devices • Polymer manufacturing
Graphite	• Rechargeable batteries • Jet engine components	• Munitions • Rechargeable batteries • Body armor • Superalloy components	• Rechargeable batteries • Nuclear applications • PEM fuel cell applications • Land based turbines	• Rechargeable batteries	• Rechargeable batteries	• Lubricant • Refractories • Electrodes • Steelmaking
Helium	NA	NA	NA	• Semiconductor manufacturing	NA	• Magnetic resonance imaging • Cryogenic cooling • Shielding gas • Tank purging • Leak detection
Indium	• Aircraft wind shield	• Infrared imaging	• Solar cells • Alkaline batteries • Nuclear applications • Light-emitting diodes	• Fiber optics • Flat-panel displays • Light-emitting diodes • Semiconductors • Thermal interface materials	NA	• Lasers • Solder
Lithium	• Rechargeable batteries • Aluminum alloys (structural)	• Rechargeable batteries • Aerospace alloys • Tritium production support	• Rechargeable batteries • Cooling water chemistry in nuclear power reactors	• Rechargeable batteries	• Rechargeable batteries	• Glass and ceramics manufacturing • Lubricant • Medical applications
Magnesium	• Aluminum alloys	• Incendiaries • Munitions • Aluminum alloys • Radar	• Lightweight alloys	NA	• Automobile components	• Metallurgical applications • Corrosion resistance

6 Draft Critical Mineral List—Summary of Methodology and Background Information

Table 2. Important technologies and applications by mineral commodity and industrial sector.—Continued

[NA, not applicable; SOFC, solid oxide fuel cell; PEM, polymer electrolyte membrane]

Mineral commodity	Aerospace (nondefense)	Defense	Energy	Telecommunications and electronics	Transportation (nonaerospace)	Other
Manganese	• Jet engines (superalloys) • Aluminum alloys	• Aluminum alloys	• Land-based turbines • Lightweight alloys • Rechargeable batteries	NA	• Aluminum alloys	• Specialty steel
Niobium	• Jet engines (superalloys)	• Jet engines (superalloys) • Specialty steels	• Land-based turbines • Oil and gas pipelines (specialty steel) • SOFC catalysts • Nickel based superalloys	NA	NA	• Superconducting alloys
Platinum-group metals	• Jet engines (casting, coatings)	NA	• Petroleum catalysts • Land-based turbines • Fuel cells • Autocatalysts	• Hard-disk drives • Capacitors • Flat-panel displays	• Autocatalysts • Fuel cells • Automotive components	• Chemical catalysts • Medical applications • Refractory crucibles • Metallurgical applications • Integrated circuits
Potash	NA	NA	• Oil and gas drilling fluid	NA	NA	• Agricultural fertilizer
Rare earth elements	• Jet engines (ceramics, superalloys)	• Guidance systems • Lasers • Radar • Sonar	• Petroleum catalysts • Permanent magnets for electric motor and wind turbines • Fuel additives • Wind turbines • Nuclear applications • Rechargeable batteries • SOFC applications • Turbines (superalloys, coating)	• Fiber optics • Signal amplifiers • Cellular phones • Flat-panel displays • Hard-disk drives • Lighting • Electric motors • Sensors	• Autocatalysts • Electric motor magnets • Automotive glass	• Steel and nonferrous alloys • Chemical catalysts • Ceramics • Permanent magnets • Polishing compounds • Lasers • Optical glass • Medical imaging • X-ray scintillometers
Rhenium	• Jet engines (superalloys)	NA	• Petroleum catalysts • Land-based turbines	• High-temperature applications	NA	• Refractory crucibles
Scandium	• Aluminum-scandium alloys	• Aluminum alloys • Lasers	• Fuel cells • Lighting • Petroleum refining	• Lasers • Lighting • Phosphors • Piezoelectrics	• Fuel cells	• Catalysts • Ceramics • Flares and pyrotechnics
Strontium	• Aluminum alloys • Superalloys	• Flares, tracer ammunition	• Oil and gas drilling • Permanent magnets	• Permanent magnets • Semiconductors	• Permanent magnets • Aluminum alloys	• Ceramics • Metal refining • Flares and pyrotechnics

Table 2. Important technologies and applications by mineral commodity and industrial sector.—Continued

[NA, not applicable; SOFC, solid oxide fuel cell; PEM, polymer electrolyte membrane]

Mineral commodity	Aerospace (nondefense)	Defense	Energy	Telecommunications and electronics	Transportation (nonaerospace)	Other
Tantalum	• Jet engines (superalloys)	• Armor-piercing munitions • Aircraft components	• Land-based turbines	• Capacitors • Cellular phones • Semiconductors • Flat-panel displays	NA	• Cemented carbides • Chemical processing equipment • Corrosion resistance • Medical devices
Tellurium	NA	• Infrared devices (night-vision) • Temperature control systems	• Solar cells	• Photoreceptor devices • Semiconductors	NA	• Specialty steels • Nonferrous alloys • Thermoelectric applications
Tin	NA	• Nonferrous alloys (bearings)	NA	• Solder • Flat-panel displays	NA	• Solder • Packaging • Polymer manufacturing • Catalysts • Glass manufacturing
Titanium	• Jet engines (superalloys) • Airframes	• Aerospace • Ground vehicle armor • Artillery • Corrosion resistance	• Oil and gas drilling equipment • Corrosion resistance • Land based turbines	NA	NA	• Medical devices • Photocatalysts
Tungsten	• Jet engines (superalloys)	• Armor-piercing munitions	• Oil and gas drilling equipment • Land-based turbines • Petroleum catalysts	• Cellular phones • Contacts • Filaments • Lighting	NA	• Cemented carbides • Specialty steels • Chemical catalysts • Corrosion resistance
Uranium	• Space missions	• Nuclear applications • Support for tritium production • Naval propulsion	• Electricity production, including supporting manufacturing	NA	NA	• Medical isotope production and development
Vanadium	• Jet engines (superalloys) • Titanium alloys	• Specialty steel • Titanium alloys • Land based turbines	• Petroleum catalysts • Grid scale batteries	NA	NA	• Chemical catalysts • Specialty steel • Titanium alloys
Zirconium and hafnium	• Jet engines (ceramics, superalloys)	• Incendiaries	• Nuclear applications • SOFC applications • Land based turbines (coating)	NA	NA	• Corrosion resistance • Technical ceramics • Chemical catalysts

Another simplification used is categorization into mineral groups. Rare earth elements, for example, include yttrium and all the lanthanides. All these elements are typically present together in mineral deposits and, thus, share the same high levels of HHI and NIR. Scandium, which is often included with yttrium and the lanthanides under rare earth elements, behaves differently in natural systems and is not necessarily always present together with the other rare earths, so it is listed separately. The platinum group elements include platinum, palladium, rhodium, ruthenium, and iridium. Hafnium is produced solely as a byproduct of zirconium processing, so the two are combined on the draft list.

Notably, several materials on the draft list are recovered only as byproducts of other more-common mineral commodities. These ubiquitous materials may not meet the criteria to be included on the draft list. Tellurium, for example, is a byproduct of copper refining. Rhenium is a byproduct of molybdenum processing. Despite these codependencies, neither copper nor molybdenum is designated as critical. Other major mineral commodities such as gold, lead, zinc, nickel, and iron also are important potential sources for byproduct critical mineral production. A strategy for addressing the special characteristics of byproduct mineral supply needs to be an important part of the report submitted on implementation of the EO. Additional discussion of byproduct mineral commodities is included in appendix 1.

There are many mineral materials not included on the draft critical minerals list that are still of substantial importance to the U.S. economy. These materials are not considered critical in the conventional sense because the United States largely meets its needs for these through domestic mining and processing; thus, a substantial supply disruption is considered unlikely. Industrial minerals, for example, are the materials that form the physical basis for much of our Nation's infrastructure. These include materials for making cement (limestone, clays, shales, and aggregates); materials (such as iron and steel) used in rebar, steel mesh, and wire grids to reinforce concrete structures; and materials on which to place infrastructure, such as base courses composed of crushed stone and aggregates. These construction commodities are the largest (by volume) sectors of the U.S. mineral industries. Other important mineral materials include inputs into the chemical industries or agricultural sector including sulfur, salt, phosphate, and gypsum. The manufacturing of products such as glass, ceramics, refractories, and abrasives require quartz, soda ash, feldspar, kaolin, ball clays, mullite, kyanite, industrial diamonds, garnets, corundum, and borates. Many others could be listed.

Finally, it should be noted that mineral criticality is not static, but rather changes over time. This analysis represents a snapshot in time that should be reviewed and updated periodically using the most recently available data to accurately capture rapidly evolving technological developments and the consequent material demands.

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Appendix 1. Criticality Methodology and Other Considerations

National Science and Technology Council Critical Mineral Early Warning Screening Methodology

The National Science and Technology Council Critical Mineral Early Warning Screening Methodology (U.S. National Science and Technology Council, 2016; McCullough and Nassar, 2017) applies a country-agnostic view when screening 77 nonfuel mineral commodities. The methodology consists of two stages, starting with an indicator-based approach that then informs deep-dive studies completed in the second stage. The three fundamental indicators used in the first stage are supply risk (*R*); production growth (*G*); and market dynamics (*M*). Each indicator aims to capture a different yet complementary aspect of criticality: *R* attempts to capture the risk associated with the concentration of production in countries with low governance, *G* evaluates the growth of world production to highlight a commodity's growing importance, and *M* examines price volatility to capture the stability of the commodity's market. The outputs provided by each indicator are normalized on a common scale from 0 to 1 in which higher values indicate a relatively higher degree of criticality. This scale gives each indicator an equal weight before being combined into a criticality potential score (*C*) through a geometric mean. Each indicator is applied consistently to every screened commodity on an annual basis. Data are primarily sourced from the U.S. Geological Survey. The minerals identified in the first stage as having a statistically significant high *C* score then undergo "deep-dive" studies in the second stage designed to closely evaluate circumstances specific to each commodity.

Production Concentration

The mining and processing of many nonfuel mineral commodities has become increasingly concentrated in only a few nations (for example, Chinese refining of cobalt). This trend reflects changes in global demand for materials, comparative advantages in production (aluminum production from low-cost energy in United Arab Emirates), or government policies to secure domestic supplies of strategic materials (beryllium in the United States), whereas historic production concentrations typically have reflected geological distributions (platinum-group metals in South Africa). Highly concentrated production is an important component of criticality for geologically derived materials. Mineral production that is concentrated in a small number of countries poses a higher risk of triggering a supply disruption than a mineral with widely dispersed production. Highly consolidated supply chains have an increased risk of supply disruption from foreign government

action, trade disputes, civil unrest, natural disasters, and other hazards. Production concentration was quantified using a metric of market concentration known as the Herfindahl-Hirschman Index (HHI), which is calculated as the sum of the squares of each producing nation's global production share of a commodity in a given year. HHI is used by the Department of Justice and the Federal Trade Commission to identify highly concentrated markets where firms exhibit elevated control above an established threshold of 2,500 on a scale that ranges from 0 to 10,000. Similarly, a threshold of 2,500 was used to identify commodities with highly concentrated production, and the largest producer of each mineral commodity was indicated.

United States Net Import Reliance

The United States relies on imports of many mineral commodities because domestic production is either lacking or insufficient to satisfy domestic demand by consumers. As a metric of this foreign dependency, net import reliance (NIR) is calculated as the amount of imported material (including changes in stockpiles) minus exports and changes in government and industry stocks and is expressed as a percentage of domestic consumption (U.S. Geological Survey, 2017). For example, a mineral commodity that is not produced in the United States has an NIR of 100 percent. When U.S. production of a mineral commodity exceeds domestic consumption, the United States is a net exporter. For this analysis, materials that require imports to satisfy more than one-half of domestic consumption are deemed to have a high U.S. NIR. The largest foreign suppliers of these targeted mineral commodities have been included in addition to the NIR to provide broader strategic context, which highlights that not only does the United States require foreign supplies, but that 12 out of the 26 commodities with high United States NIR are sourced primarily from China. However, high NIR should not be construed to always pose a potential supply risk. For example, three of the commodities deemed critical or near critical are primarily imported from Canada, a nation that is integrated with the United States defense industrial base.

Byproduct Commodities

Many commodities are not mined directly, but are instead recovered during the processing, smelting, or refining of a host material and are, therefore, deemed "byproducts" (fig. 1.1). These byproducts are typically chemically similar to their host material and are present in the same ores, albeit at a small fraction of the concentration (for example, tellurium in copper

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Appendix 2. Brief Commodity Summaries—Critical Minerals

Table 2.1. Critical mineral commodity summaries.

[Commodities are listed alphabetically. Supply chain considerations were utilized in the selection process, meaning a commodity is included if any step in its supply chain is deemed problematic. Information in this table is from U.S. Geological Survey (2017, 2018, variously dated)]

Mineral commodity	Summary
Aluminum	Historically, the United States has had a low import reliance on aluminum metal, although this has been changing in recent years because of the loss of domestic smelting capacity; moreover, production of aluminum has become increasingly concentrated in China in recent years. The larger concern for aluminum is, however, the bauxite ore, on which the United States is highly import reliant, which is used to produce alumina (the feedstock for primary aluminum smelters). Bauxite is imported from tropical regions, dominantly Jamaica, as well as Brazil, Guinea, and Guyana. Alumina imports from Australia and Brazil are important sources for specific aluminum smelters, although these imports generally are offset by alumina exports.
Antimony	Antimony is not mined domestically. The United States produces primary antimony metal and oxide from imported feedstocks and secondary (recycled) antimony from antimonial lead recovered from spent lead-acid batteries. Alloys of antimony and lead provide enhanced electrical properties to batteries. In addition to its use in antimonial lead for lead-acid batteries, other major uses are flame-retardants, lead alloys, as a catalyst for plastics, polyvinyl chloride stabilizers, ceramics, and glass.
Arsenic	Despite an abundance of domestic resources, primary arsenic metal has not been produced in the United States in decades. Arsenic is used mostly as arsenic trioxide for the generation of chromated copper arsenide for pressure-treating lumber. However, arsenic, as a metal, also has uses as a hardener for lead alloys and in gallium arsenide semiconductors. The United States is reliant entirely on imports, largely from China and Morocco. Currently (February 2018), arsenic is not recovered from end-of-life electronics. Manufacturers, however, recycle new scrap.
Barite	Barite is used overwhelmingly in the oil and gas industry as a high-density component of drilling mud, and consumption mirrors the activity of the petroleum industry. The United States is highly reliant on barite imports, largely from China, and additional concerns address the supply of high-specific-gravity material required by the petroleum industry. Recent exploration of domestic barite resources has been limited, although significant resources have been identified.
Beryllium	The United States produces about 85 percent of global beryllium mine production from one deposit in Utah, and the remainder is produced in China and other countries. Only three countries process beryllium ores into beryllium products: China, Kazakhstan, and the United States. Most beryllium is used to make beryllium-copper and other alloys, whereas 20 percent of consumption is in the form of beryllium metal, composites, and oxides. Beryllium alloys are used widely in telecommunications, electrical components, electronics, and many other products. Beryllium metal is used mainly in defense, aerospace, and nuclear applications. The Defense Logistics Agency maintains an inventory of beryllium metal in the National Defense Stockpile. The only domestic beryllium metal processing facility was constructed under Title III of the Defense Production Act and began operation in 2012.
Bismuth	Aside from small quantities of bismuth recycled from old and new scrap, all bismuth consumption in the United States is imported, mainly from China, which is the world's largest producer. Bismuth is contained in some of the lead ores mined domestically, but all lead concentrate is exported for smelting since the closure of the last primary lead smelter in 2013. Bismuth has major applications in chemicals for cosmetic, industrial, laboratory, and pharmaceutical uses. Bismuth also is used in a number of metallurgical applications, including use as a nontoxic replacement for lead. Bismuth can be replaced in many of its major applications.
Cesium and rubidium	The United States relies on imports for cesium and rubidium. Only a few thousand kilograms of cesium and rubidium are consumed in the United States every year. By gross weight, cesium formate brines used for high-pressure, high-temperature well drilling for oil and gas production and exploration are the primary applications for cesium. Rubidium is used in specialty glass and night-vision devices. The United States sourced most of its pollucite, the principal mineral source of cesium, from the largest known deposit in North America at Bernic Lake, Manitoba, Canada; however, that operation ceased mining at the end of 2015 but continued to produce cesium products from stocks. The company indicated it had sufficient stocks of raw materials to continue producing its cesium products for the near future. Rubidium concentrate is produced as a byproduct of pollucite (cesium) and lepidolite (lithium) mining and is imported from other countries for processing in the United States.

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Table 2.1. Critical mineral commodity summaries.—Continued

[Commodities are listed alphabetically. Supply chain considerations were utilized in the selection process, meaning a commodity is included if any step in its supply chain is deemed problematic. Information in this table is from U.S. Geological Survey (2017, 2018, variously dated)]

Mineral commodity	Summary
Chromium	Chromium is used predominantly in the production of stainless steel and superalloys where it adds temperature and corrosion resistance. U.S. chromite reserves are small, with no mining, resulting in chromium-bearing materials being produced from imported chromite ores and ferrochromium. Globally, South Africa has the largest chromite reserves and is the leading source of chromium-bearing imports. Limited substitutes exist for chromium in alloy applications; however, recycling is extensive, accounting for about 40 percent of consumption.
Cobalt	Congo (Kinshasa) is increasingly becoming a dominant miner of cobalt, with more than one-half of world production in 2016. This production was mainly a byproduct of copper operations. Cobalt also is recovered as a byproduct of nickel mining in Russia and other countries. Like the United States, China lacks sufficient domestic supplies for its industries and, thus, has aggressively sought to secure its supplies through overseas acquisitions. Cobalt demand is expected to grow significantly because of its use in rechargeable batteries for electric vehicles and other technologies. Other uses of cobalt are in superalloys for jet engines and cemented carbides for cutting tools and wear-resistant applications.
Fluorspar	The United States is highly import reliant on foreign sources of fluorspar, chiefly Mexico, with limited domestic production. Fluorspar's uses typically are categorized into three broad categories: in the production of hydrofluoric acid, in the production of aluminum fluoride (essential for aluminum smelting), uranium processing, and as a flux in steelmaking. Fluorspar also is important in the manufacturing of welding rods. Through its use in the production of hydrofluoric acid, it is the main source of fluorine in almost all chemical applications. The United States produces fluorosilicic acid from phosphate processing; however, this potential domestic fluorine source has not been widely adopted for acid generation and metallurgical uses.
Gallium	Gallium is recovered primarily as a byproduct of processing bauxite; smaller quantities are recovered from zinc processing residues. No primary gallium has been recovered in the United States since 1987. Current production of low-grade, unrefined gallium is dominated by China; however, the United States can and does refine gallium to high-grade from primary low-grade gallium imports and from new scrap (recycled materials). Gallium finds major application in integrated circuits and optoelectronic devices such as light emitting diodes, photodetectors, and solar cells.
Germanium	Germanium is a minor constituent of some lead and zinc ores mined in the United States. The United States lacks processing facilities for recovering germanium from primary ores. Zinc concentrates containing germanium are exported to Canada and Belgium for processing and germanium recovery. The United States is reliant on imports of processed material or end products. Currently (February 2018), China is by far the world's largest germanium producer. Germanium is used in fiber optics, infrared optics, electronics, and solar cells.
Graphite (natural)	China is by far the largest producer of natural graphite, accounting for roughly two-thirds of world production. Only 4 percent of the world's natural graphite comes from North America, with no U.S. production in decades. Although natural graphite was not produced in the United States in 2016, about 98 U.S. firms, primarily in the Northeastern and Great Lakes regions, consumed graphite in various forms from imported sources for use in brake linings, foundry operations, lubricants, refractory applications, and steelmaking. Graphite's use in rechargeable batteries, as well as technologies under development (such as large-scale fuel-cell applications), could consume as much graphite as all other uses combined.
Helium	Helium is extracted from natural gas produced in the United States. Crude helium production exceeds domestic consumption, making the United States a net exporter of helium. Helium is used in magnetic resonance imaging, welding, semiconductor manufacturing, analytical and laboratory applications, engineering and scientific applications, and various other uses. The Bureau of Land Management manages the Federal Helium Program. Public law requires the Bureau of Land Management to dispose of all Federal helium-related assets when the remaining helium stockpile falls below 83 million cubic meters or no later than 2021.
Indium	Indium is primarily consumed as indium tin oxide, largely in flat-panel displays. Other notable uses of indium include semiconductors and low-temperature alloys. Indium is recovered as a byproduct of zinc ores. Although the United States has substantial production of zinc ore, there is no recovery of indium from ores in the United States. The United States is, therefore, exclusively reliant on imports. China is the world's largest producer of indium; however, Canada is the largest source of United States imports. New indium tin oxide (manufacturer's) scrap is recycled domestically, though there is limited information on the quantity of this production. There are no known commercial substitutes for indium tin oxide in flat-panel displays.

Table 2.1. Critical mineral commodity summaries.—Continued

[Commodities are listed alphabetically. Supply chain considerations were utilized in the selection process, meaning a commodity is included if any step in its supply chain is deemed problematic. Information in this table is from U.S. Geological Survey (2017, 2018, variously dated)]

Mineral commodity	Summary
Lithium	Lithium can be recovered from hard-rock deposits and brines. Lithium demand is expected to grow substantially because of its use in rechargeable batteries, particularly for electric vehicles. Lithium hydroxide also is used for cooling water chemistry control in pressurized water reactors and may be required in some advanced concept nuclear reactors (molten salt). The U.S. import reliance is moderate, but increasing foreign consumption in addition to U.S. demand growth has driven a substantial exploration boom.
Magnesium	Magnesium metal is produced from brines, which are virtually unlimited in comparison to demand. The United States only has one magnesium metal producer, which creates a potential single point of failure. Magnesium metal production is an important component of domestic titanium production; therefore, the loss of this domestic producer could result in broader effects. The United States only has a moderate import reliance on magnesium metal; Israel and Canada provide more than 50 percent of imports. There is substantial secondary recovery from magnesium castings and aluminum alloys that is comparable to the reported primary consumption.
Manganese	The United States has not mined manganese in decades and is reliant entirely on imports of manganese for ferroalloys, silicomanganese, and chemical compounds, and ore and alloy imports largely come from African nations and Australia. The United States does not possess economically viable resources, and manganese only is recycled incidentally during steel scrap processing.
Niobium	Most of the world's niobium production comes from one country, Brazil. Niobium is used primarily in high-strength low-alloyed steels that are necessary for infrastructure development and superalloys in the aerospace industry. Like the United States, China has no domestic niobium primary production and has invested in overseas acquisitions to secure its supplies. As developing countries construct their infrastructure and developed nations, including the United States, redevelop theirs, demand for niobium will likely increase.
Platinum-group metals	Platinum-group-metal (PGM) production is concentrated in South Africa and, to a lesser degree, in Russia and Zimbabwe. Although some primary PGMs are produced in the United States, as well as secondary (recycled) production, these are insufficient to satisfy domestic demand. Economic conditions, labor issues, and electricity shortages in South Africa in recent years have highlighted the risk associated with high production concentration in a single country. PGMs are used in a wide variety of applications ranging from electronics to anticancer drugs and biomedical devices to glass manufacturing equipment but are especially widely used as catalysts. Use in catalytic converters for the reduction of harmful emissions from internal combustion engines is essential but are likely to decrease with increased use of electric vehicles. Given their high value, PGMs have relatively high recycling rates except in their use in electronic applications because of the lack of collection of postconsumer electronics. Substitution of PGMs is limited because PGMs often are the best substitutes for other PGMs.
Potash	Potash denotes a variety of mined and manufactured salts that contain the element potassium in water-soluble form. Potash is used extensively in agriculture; fertilizers account for more than 85 percent of use, and the chemical industry accounts for the remainder. The United States is 90 percent reliant on imports to meet domestic demand for potash, and 85 percent of potash imports originate in Canada. Potash is produced in New Mexico and Utah from underground mining of ores and processing of brines. Estimated domestic potash resources total about 7 billion tons, whereas domestic reserves are estimated to be about 520 million tons. No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans.
Rare earth elements	With the closure of the Mountain Pass Mine in California, rare earth elements (REEs) are not mined in the United States. Most REEs, especially heavy REEs, are mined and processed in China. REEs are used in a wide range of applications ranging from magnets to phosphors for which there are limited substitutes. Furthermore, little postconsumer recycling happens for most of the REEs. Efforts by the Critical Materials Institute to develop substitutes and enhance recycling technologies are ongoing.
Rhenium	Rhenium is used primarily as an alloying agent in high-temperature steels for jet engines. Rhenium is produced as a byproduct of molybdenum, which itself is often a byproduct of porphyry copper mining. Although rhenium is present in domestic molybdenum-copper resources, the United States has insufficient processing capacity to meet domestic demand for rhenium. The United States ships rhenium-bearing molybdenum concentrates to Chile for recovery and imports refined rhenium. Rhenium recycling plays an important role in its global supply, but demand for new commercial and military jet aircraft will likely make it impossible for recycling alone to be sufficient. Given its high value and small market, substitution of rhenium is evaluated continually, and some substitutes have achieved commercial success. Reduced rhenium and rhenium-free alloys are being evaluated currently (2018) by major aerospace companies.

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Table 2.1. Critical mineral commodity summaries.—Continued

[Commodities are listed alphabetically. Supply chain considerations were utilized in the selection process, meaning a commodity is included if any step in its supply chain is deemed problematic. Information in this table is from U.S. Geological Survey (2017, 2018, variously dated)]

Mineral commodity	Summary
Scandium	Scandium-bearing minerals are neither mined nor recovered domestically from mine tailings. The principal source for scandium metal and scandium compounds is imports from China. The principal uses for scandium are in aluminum-scandium alloys and solid oxide fuel cells. Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes used as tracing agents in oil refining.
Strontium	The United States is completely import reliant for strontium, sourcing all celestite from Mexico and other strontium compounds from Mexico, Germany, and China. Historically, the United States did have some domestic production of strontium carbonate, but this ended in 2006. Several companies do produce downstream chemicals domestically but in small amounts.
Tantalum	There has been no substantial U.S. domestic production of tantalum since the 1959. Moreover, tantalum is the only conflict mineral (the other three being tungsten, tin, and gold) whose primary production is mostly in the Great Lakes region of Africa, namely in Rwanda, the Democratic Republic of the Congo (Kinshasa), and, to a lesser extent, Burundi. Large, conventional tantalum mines in developed countries, including Australia and Canada, have largely been placed on care and maintenance indefinitely because of competition from lower-cost artisanal operations in Africa. Tantalum has a number of important uses in electronics, mainly in capacitors, and in superalloys that are used in jet engines and gas turbines.
Tellurium	Tellurium is recovered mainly as byproduct of anode slimes from certain copper refineries. Most of the tellurium contained in the copper anode slimes is not recovered currently (2018). Therefore, tellurium production in the United States and globally could be increased substantially without increasing copper production, but only under the appropriate economic conditions. Tellurium demand may increase substantially if the solar photovoltaic technology that uses tellurium, namely cadmium telluride, gains market-share. There are, however, a number of competing solar photovoltaic technologies. Aside from solar cells, tellurium's other major uses include thermoelectric devices and thermal imaging devices. Tellurium also is used in metallurgical applications.
Tin	Tin has a wide variety of end uses, including containers, chemicals, nonferrous alloys, and solders. U.S. mineral reserves of tin are small, and neither domestic mining nor smelting has happened in more than 20 years. However, tin has robust recycling from old (postconsumer) and new (manufacturing) scrap in the United States. The United States relies entirely on foreign imports of primary smelted tin; however, these imports are distributed broadly between South America and Southeast Asia. China is the world's largest miner of tin, providing more than one-third of the world's production.
Titanium	The United States is highly import reliant on titanium mineral concentrates, which have a variety of uses including pigments but also are required for metal production. The United States has a moderate import reliance on titanium metal (sponge), and imports mostly scrap and raw metal, while exporting finished wrought products. Titanium mineral reserves exist in the southeastern United States; however, these reserves are small compared to foreign supplies. Titanium recycling makes up a substantial part of domestic consumption, and few acceptable substitutes exist. Titanium is critical in aerospace components, in rotating parts in turbine engines, and for its use in corrosive environments.
Tungsten	Tungsten is produced domestically from imported materials or recovered from waste and scrap. China possesses the world's largest tungsten reserves and also is the largest producer with more than 80 percent of the world's primary production. China also supplies nearly 40 percent of tungsten material imported to the United States. Tungsten materials are widely recycled, which decreases foreign reliance. Substitutes for tungsten in high-wear and high-density applications exist and could reduce tungsten consumption, albeit at both increased price and performance loss.
Uranium	Uranium is critical for U.S. defense needs, energy production, the development of medical isotopes and energy generation in space vehicles and satellites. Current (2018) U.S. Department of Energy inventory is meeting most defense needs in the short term. However, U.S. sourced uranium will be needed in the future to meet defense requirements that, according to international agreements, must be free from peaceful use restrictions. Uranium also is critical in ensuring a reliable supply of fuel for the 99 nuclear power reactors that supply about 20 percent of U.S. electricity. Only 8 percent of uranium loaded into U.S. nuclear power reactors in 2016 was of U.S. origin; the remaining 92 percent was imported uranium. Under the American Isotope American Medical Isotope Production Act of 2012, the U.S. Department of Energy carries out a program of assistance for the development of fuels, targets, and processes for domestic molybdenum-99 medical isotope production. Uranium also is needed for production of fuel for certain space missions.

Table 2.1. Critical mineral commodity summaries.—Continued

[Commodities are listed alphabetically. Supply chain considerations were utilized in the selection process, meaning a commodity is included if any step in its supply chain is deemed problematic. Information in this table is from U.S. Geological Survey (2017, 2018, variously dated)]

Mineral commodity	Summary
Vanadium	Vanadium production is concentrated largely in a small number of foreign producers, including China (with more than one-half of world production), South Africa, Russia, and, increasingly, Brazil. The U.S. import reliance of vanadium is high, largely for consumption in alloy steel production. However, substantial domestic resources exist, although there is currently no primary production.
Zirconium and hafnium	Zirconium is recovered as a coproduct of mining and processing titanium and zircon mineral concentrates in Florida and Georgia. In addition to domestic sources of zirconium, the United States imports zircon mineral concentrates, mainly from South Africa, zirconium metal from China, as well as zirconium chemicals. Zirconium metal and hafnium metal are produced in Oregon and Utah from zirconium chemical intermediates. Typically, zirconium and hafnium are contained in zircon at a ratio of about 50 to 1, respectively. The leading consumers of zirconium metal are the nuclear energy and chemical process industries, whereas hafnium metal is used in superalloys for jet engines and land-based turbines.

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