United States Government Accountability Office

Report to the Chairman, Committee on Energy and Natural Resources, U.S. Senate

September 2016

ADVANCED TECHNOLOGIES

Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials

Accessible Version

GAO-16-699

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GAO Highlights

Highlights of GAO-16-699, a report to the Chairman, Committee on Energy and Natural Resources, U.S. Senate

Why GAO Did This Study

Certain metals, minerals, and other "critical" raw materials play an important role in the production of advanced technologies across a range of industrial sectors and defense applications. Recently, concentration of the supply of some critical materials under foreign control has renewed questions about the U.S. government's and industry's ability to address potential supply disruptions.

GAO was asked to examine U.S. efforts to identify and strategically plan for critical materials supply issues. Among other objectives, this report (1) describes federal agencies' activities related to the supply of critical materials and (2) evaluates the federal government's approach to addressing critical materials supply issues. GAO reviewed relevant laws, agency documents, and academic studies; interviewed federal officials; and conducted a two-stage web-based survey of a nongeneralizable sample of critical materials experts selected to cover a range of subject matter areas.

What GAO Recommends

GAO is making six recommendations, including that OSTP take steps to improve interagency collaboration by, for example, defining Subcommittee member roles and responsibilities and that Commerce engage with stakeholders to continually identify and assess critical materials needs across industrial sectors. Commerce agreed. OSTP agreed with one and neither agreed nor disagreed with the other four recommendations but discussed how roles and responsibilities are defined, among other things. GAO continues to believe these steps are needed, as discussed in the report.

View GAO-16-699. For more information, contact John Neumann at (202) 512-3841 or neumannj@gao.gov.

What GAO Found

Federal agencies are primarily focused on two areas of activity related to critical materials supply—assessing risk and supporting research. For example, the Department of Energy (DOE) has conducted two criticality assessments on materials important to clean energy applications and manages the Critical Materials Institute—a 5-year, $120 million investment aimed at mitigating risks by diversifying supply, providing alternatives to existing materials, and improving recycling and reuse. In addition, agencies conduct a range of other critical materials related activities, including stockpiling or producing materials, and reviewing and approving resource extraction projects, among other efforts.

The federal approach to addressing critical materials supply has areas of strength but is not consistent with selected key practices for interagency collaboration and faces other limitations, as shown below.

Selected Strengths and Limitations of Federal Critical Materials Activities

Strengths	Limitations
• Existence of an interagency subcommittee to support interagency collaboration • U.S. Geological Survey information on mineral resources • Department of Energy's Critical Materials Institute	• Interagency collaboration is not consistent with selected key practices • Federal focus on only a subset of materials for assessing critical materials supply issues • Limited focus on developing domestic resources • Limited federal government engagement with industry stakeholders

Source: GAO analysis of expert survey and information collected from agency officials. | GAO-16-699

- According to its charter, the Subcommittee on Critical and Strategic Mineral Supply Chains (Subcommittee)—co-chaired by the Office of Science and Technology Policy (OSTP), DOE, and the Department of the Interior—is to facilitate a strong, coordinated effort across its member agencies on critical materials activities. However, the Subcommittee's efforts have not been consistent with selected key practices for interagency collaboration, including agreeing on roles and responsibilities; establishing mutually reinforcing or joint strategies; and developing mechanisms to monitor, evaluate, and report on results. For example, some member agencies do not have a clear role in the Subcommittee's efforts and have had limited or no involvement in its work. By taking steps to actively engage all member agencies in its efforts and clearly define roles and responsibilities, the Subcommittee would have more reasonable assurance that it can effectively marshal the potential contributions of all member agencies to help identify and mitigate critical materials supply risks.
- Other limitations to the federal approach to addressing critical materials supply include limited engagement with industry and a limited focus on domestic production. For example, the Department of Commerce (Commerce) is required by law to identify and assess cases of materials needs. However, Commerce does not solicit information from stakeholders across a range of industrial sectors. As a result, Commerce may not have comprehensive, current information across a range of industrial sectors to help it identify and assess materials needs.

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Abbreviations

1980 Act	National Materials and Minerals Policy, Research and Development Act of 1980
BLM	Bureau of Land Management
CEQ	Council on Environmental Quality
CMI	Critical Materials Institute
Commerce	Department of Commerce
DHS	Department of Homeland Security
DLA-Strategic Materials	Defense Logistics Agency-Strategic Materials
DOD	Department of Defense
DOE	Department of Energy
Education	Department of Education
EPA	Environmental Protection Agency
EU	European Union
FTS	flow-through share
G7	Group of Seven
HHS	Department of Health and Human Services
Interior	Department of the Interior
Isotope Program	Isotope Development and Production for Research and Applications program
ITA	International Trade Administration
JOGMEC	Japan Oil, Gas and Metals National Corporation
Justice	Department of Justice
Labor	Department of Labor
METC	Mineral Exploration Tax Credit
METI	Ministry of Economy, Trade, and Industry
MPMO	Major Projects Management Office
NASA	National Aeronautics and Space Administration
NEC	National Economic Council
NIH	National Institutes of Health
NSC	National Security Council
NSF	National Science Foundation
NSTC	National Science and Technology Council
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
Partnership	European Innovation Partnership on Raw Materials
State	Department of State

STEM	science, technology, engineering, and mathematics
Subcommittee	Subcommittee on Critical and Strategic Mineral Supply Chains
Treasury	Department of the Treasury
UN	United Nations
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USTR	Office of the U.S. Trade Representative
WTO	World Trade Organization

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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September 7, 2016

The Honorable Lisa Murkowski
Chairman
Committee on Energy and Natural Resources
United States Senate

Dear Madam Chairman:

Many advanced technologies rely on certain metals, minerals, or other "critical" raw materials for their production.[1] In some cases, specific materials are important to advanced technologies because of their unique chemical and physical properties. For example, the rare earth materials neodymium and dysprosium are used in the manufacture of permanent magnets, which are used in automotive motors, wind turbines, and a variety of other applications because of their unique properties, such as magnetism at high temperatures.[2] For some critical materials, a majority of the global supply is produced by a few suppliers, in a single country, or comes from a region that is vulnerable to geopolitical unrest. For example, as we previously reported, China produces most of the world's supply of rare earth materials, which are used in cell phones, computer hard drives, precision-guided munitions, and a variety of other commercial and military applications.[3] In 2010, China tightened its export restrictions on rare earth materials and a rapid price increase followed. According to a 2013 Congressional Research Service report, from April

[1]For the purposes of this report, we are defining a "critical material" as one that is subject to supply risk, such as a single source of production or geopolitical unrest; has limited substitutability; and has an end use that is important to U.S. economic or national security interests.

[2]Rare earth materials contain 1 or more of the 17 chemical elements beginning with lanthanum (element number 57 in the periodic table) up to and including lutetium (element number 71), as well as yttrium and scandium, which have similar properties. These elements are referred to as rare because they appear in low concentrations in the ground—though relatively abundant overall—and are difficult and costly to mine and process.

[3]GAO, *Rare Earth Materials in the Defense Supply Chain*, GAO-10-617R (Washington, D.C.: Apr. 14, 2010). According to the U.S. Geological Survey, in 2015 China accounted for about 85 percent of the world mine production of rare earth materials, excluding scandium.

2010 to July 2011, the prices of dysprosium and neodymium rose from $250 per kilogram to $2,840 per kilogram and from $42 per kilogram to $334 per kilogram, respectively.[4] This price volatility highlighted U.S. dependence on China for these materials and the potential supply risks for U.S. defense and economic interests. Moreover, limitations on the availability of critical materials to U.S. companies at acceptable prices have the potential to affect the development of emerging advanced technologies and the industrial sectors that produce them.

A stable supply of critical materials has long been recognized as an important U.S. issue. In 1980, Congress passed the National Materials and Minerals Policy, Research and Development Act (1980 Act), citing the lack of a coherent national materials policy and a need for a coordinated program to ensure the availability of materials critical for national economic well-being, defense, and industrial production.[5] In recent years, the concentration of the supply of some critical materials under foreign control has renewed questions about the U.S. government's and industry's ability to address potential critical materials supply disruptions. In 2010, the National Science and Technology Council's (NSTC) Committee on Environment, Natural Resources, and Sustainability chartered the Subcommittee on Critical and Strategic Mineral Supply Chains (Subcommittee) to provide advice and assistance on policies, plans, and procedures for mitigating mineral risks.[6] In addition, a number of bills have been introduced in the 113th and 114th Congresses that seek to address critical material supply issues through a variety of proposals, such as streamlining mine permitting in the United

[4]Congressional Research Service, *Rare Earth Elements: The Global Supply Chain*. (Washington, D.C.: Dec. 16, 2013).

[5]Pub. L. No. 96-479, 94 Stat. 2305 (1980) (codified at 30 U.S.C. §§ 1601-1605 (2016)).

[6]The NSTC was established by executive order on November 23, 1993. Exec. Order No. 12,881, 3 C.F.R. 679 (1993). This cabinet-level council is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the federal research and development enterprise. A primary objective of the NSTC is establishing clear national goals for federal science and technology investments spanning virtually all the mission areas of the executive branch. The NSTC's work is organized under five committees: (1) Environment, Natural Resources, and Sustainability; (2) Homeland and National Security; (3) Science, Technology, Engineering, and Math Education; (4) Science; and (5) Technology. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology.

States, increasing critical materials data collection, and conducting research on material substitution and recycling.

You asked us to examine the status and comparative strength of U.S. efforts to identify and strategically plan to address critical materials supply issues. This report (1) describes federal agencies' activities related to the supply of critical materials; (2) describes the approaches of selected countries and regions to address critical materials supply issues; and (3) evaluates the federal government's approach, such as coordination of activities, to addressing critical materials supply issues.

For our first and third objectives, we reviewed critical materials-related laws, such as the 1980 Act and a law related to the Department of Defense's stockpiling of materials, regulations, industry reports, and academic studies. To describe federal agencies' activities related to the supply of critical materials, we contacted the 20 federal departments and agencies (referred to collectively as agencies) and Executive Office of the President organizations that are designated as members of the Subcommittee. These agencies and organizations are the Departments of Agriculture (USDA), Commerce (Commerce), Defense (DOD), Education (Education), Energy (DOE), Homeland Security (DHS), the Interior (Interior), Justice (Justice), Labor (Labor), State (State), and the Treasury (Treasury) as well as the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), Council on Environmental Quality (CEQ), National Economic Council (NEC), National Security Council (NSC), Office of Management and Budget (OMB), Office of Science and Technology Policy (OSTP), and Office of the U.S. Trade Representative (USTR). We interviewed and obtained reports and analyses from officials from those agencies as appropriate. We also interviewed officials from a federal agency that was not designated as a member of the Subcommittee—the Department of Health and Human Services' (HHS) National Institutes of Health (NIH)—about its role in activities related to the supply of critical materials, as it relies on rare gases, for example, for research and medical applications.

To describe the approaches of selected countries and regions to address critical materials supply issues, we interviewed officials across government, academia, and industry from the European Union (EU), Japan, and Canada. We selected the EU, Japan, and Canada based on the efforts they have under way to address critical materials supply risks and our ability to collect information about those efforts.

To evaluate the federal government's approach to addressing critical materials supply issues, we developed and disseminated a two-stage, web-based survey to a nongeneralizable sample of 46 critical materials experts.[7] We selected these experts to ensure coverage of a variety of types of organizations, including industry, industry associations, academia, and government. We also selected these experts with expertise across a range of critical materials-related subject matter areas, including materials science, industrial ecology, mining and raw materials, markets and trade policy, supply chain management, and workforce issues. We conducted the survey in two rounds. The first round of the survey asked the experts to respond to five open-ended questions about the primary strengths and weaknesses of the U.S. federal government's policies and activities related to critical materials and challenges and options for improving these efforts. We conducted the first round of the survey in September and October 2015 and received responses from 33 of the 46 experts. We analyzed the responses provided by the experts in the first round and developed closed-ended questions for the second round of the survey, in which we asked each expert to rate the ideas and other information that came from the first round of the survey. We conducted the second round in February and March 2016 and received responses from 36 of the 46 experts. In addition, we interviewed officials in OSTP and other agencies that are members of the Subcommittee to obtain additional information on the federal approach, including efforts to coordinate federal activities across agencies. To evaluate the federal approach, including coordination, we compared federal efforts against the national policy outlined in the 1980 Act and selected key practices for interagency collaboration.[8] We selected the key practices based on which of the practices were most relevant to the operations of the Subcommittee. Additional information on our methodology and the experts who participated in our survey is found in appendix I.

We conducted this performance audit from March 2015 to September 2016 in accordance with generally accepted government auditing

[7]Because this was a nongeneralizable sample of experts, their views cannot be generalized to all critical materials experts but can provide illustrative examples.

[8]GAO, *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies*, GAO-06-15 (Washington, D.C.: Oct. 21, 2005), and *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms*, GAO-12-1022 (Washington, D.C.: Sept. 27, 2012).

standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

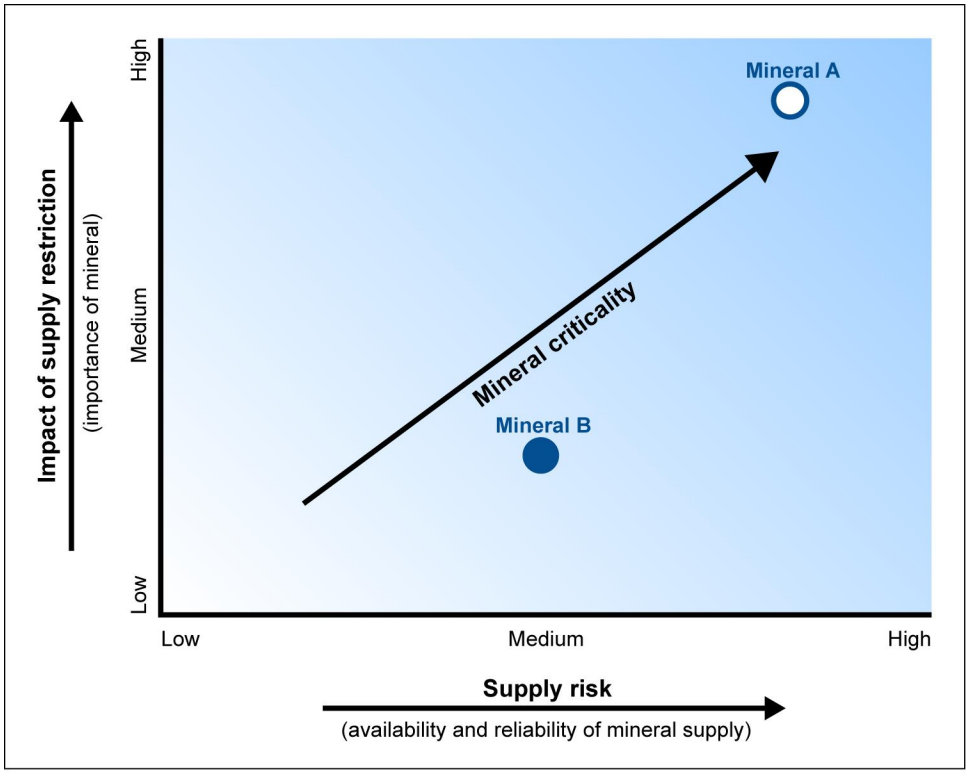
This section provides an overview of material criticality and federal agencies' critical materials roles.

Material Criticality

There is no single federal government-wide definition or list of what constitutes a critical material and different assessments have demonstrated that there are a wide variety of materials that are critical to U.S. economic and national security interests. In a 2008 study on critical minerals, the National Academies of Sciences, Engineering, and Medicine's Committee on Critical Mineral Impacts on the U.S. Economy developed a matrix to assess the criticality of a given mineral (see fig. 1).[9] The horizontal axis represents the availability and reliability of the mineral supply (supply risk), and the vertical axis represents the importance of the mineral (impact of supply restriction). The degree of criticality increases from the lower-left to the upper-right corner of the figure, such that mineral A is considered more critical than mineral B.

[9]Until May 2016, the National Academies of Sciences, Engineering, and Medicine was known as the National Research Council. National Research Council, *Minerals, Critical Minerals, and the U.S. Economy* (Washington, D.C.: 2008). See app. II for a comparison of the results of selected U.S. critical materials assessments.

Figure 1: Criticality Matrix Developed by the National Academies of Sciences, Engineering, and Medicine's Committee on Critical Mineral Impacts on the U.S. Economy



Source: National Research Council, *Minerals, Critical Minerals, and the U.S. Economy* (Washington, D.C.: 2008). | GAO-16-699

A determination that a mineral or other type of material is critical is generally based on some measure of the material's importance, combined with a measure of the supply risk for the material. Supply risks include potential physical interruptions in the supply chain, market imbalances, and government interventions.[10] For example, see the following:

[10]L. Erdmann and T. E. Graedel, " Criticality of Non-Fuel Minerals: A Review of Major Approaches and Analyses," *Environmental Science & Technology*, vol. 45, no. 18 (2011).

- Physical disruptions in the supply chain may include war or natural disasters.
- Market imbalances may include oligopoly market power or inability to adjust supply quickly in response to changes in demand.
- Government interventions may include export bans or restrictions on mining for environmental considerations.

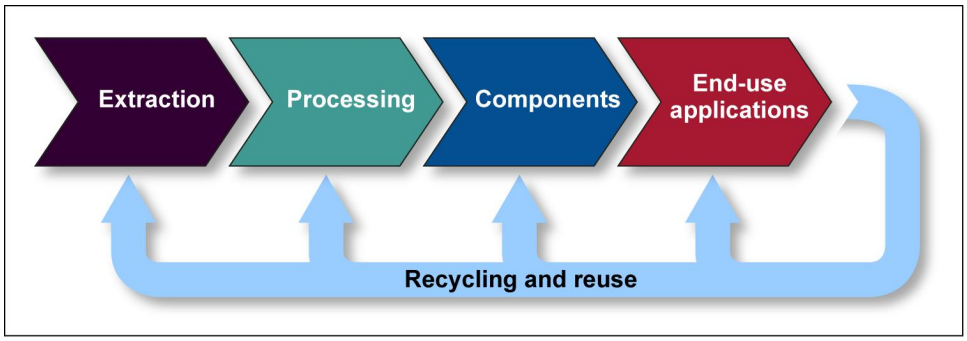
Vulnerability to potential supply disruption varies depending on the importance of the material in question and other factors, such as the extent to which acceptable substitute materials are available and the extent to which supply of a critical material can be adjusted quickly in response to changes in demand. For materials that are extracted as coproducts or by-products of other mining operations, increased demand may not cause mining companies to produce more of them without additional sustained demand for their primary products. For example, according to a journal article, ruthenium is obtained almost entirely as a by-product of platinum production.[11] In late 2006, demand for ruthenium expanded rapidly, in part, because of its increased use in hard disk drives. However, the supply of ruthenium did not respond to this increased demand, and the price of ruthenium rose rapidly to $870 per troy ounce by mid-February 2007, a ninefold increase from the previous year and a 29-fold increase from a low point in 2003.[12]

The materials supply chain in figure 2 shows the steps by which materials are extracted from mines, processed, transformed into semifinished components, and incorporated into end-use applications. The supply chain also shows the potential for recycling and reusing materials from finished applications, although materials can be reclaimed at any stage of the supply chain.

[11]N. T. Nassar, T. E. Graedel, and E. M. Harper, "By-product Metals Are Technologically Essential but Have Problematic Supply," *Science Advances*, vol.1, no. 3 (2015).

[12]According to the National Institute of Standards and Technology's handbook, *Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality*, the unit of measure and the method of sale of precious metals, if the price is based in part or wholly on a weight determination, shall be either troy weight or units from the International System of Units (the metric system). A troy ounce is approximately 31.1 grams.

Figure 2: Materials Supply Chain



Source: Department of Energy, *Critical Materials Strategy* (Washington, D.C.: 2011). | GAO-16-699

Note: This graphic conveys a conceptual critical materials supply chain. However, not all critical materials are mined materials, and the actual segments of the supply chain may vary for different critical materials.

Federal Agencies' Critical Materials Roles

There are a variety of ways in which federal agencies' activities intersect with critical materials supply issues. For example, the federal government relies on advanced technologies in which critical materials may be used to support DOD's national defense mission. DOD is responsible for determining which materials are strategic and critical for national defense and acquiring those materials. In addition, DOE, in support of its mission of ensuring the United States' security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions, is focused on the supply of critical materials given the importance of such materials to certain energy and nuclear security technologies. The federal government may also affect the development of critical materials resources through its land management and regulatory activities. For example, the Department of the Interior's Bureau of Land Management (BLM) manages approximately 950 million acres of the nation's land, including subsurface acres, and has a role in reviewing and approving resource extraction projects on this land.

The 1980 Act establishes a national policy of promoting an adequate and stable supply of materials necessary to maintain national security, economic well-being, and industrial production with appropriate attention to a long-term balance among resource production, energy use, a healthy environment, natural resources conservation, and social needs. The 1980 Act generally does not ascribe desired outcomes and responsibility for critical materials activities to individual agencies. However, the act does require the Secretary of Commerce, in consultation with other agencies,

to continually identify and assess material needs cases to ensure an adequate and stable supply of materials to meet national security, economic well-being, and industrial production needs. The act also charges the President, through the Executive Office of the President, with coordinating federal departments and agencies to undertake a variety of activities to implement this policy, including

- establishing early warning systems for materials supply problems;
- promoting a vigorous, comprehensive, and coordinated program of materials research and development;
- encouraging federal agencies to facilitate availability and development of domestic resources to meet critical materials needs;
- providing for improved collection, analysis, and dissemination of scientific, technical, and economic materials information and data from federal, state, and local governments and other sources as appropriate; and
- assessing federal policies that adversely or positively affect all stages of the materials cycle, from exploration to final product recycling and disposal.

The Subcommittee was organized as an interagency working group to help understand the issues that surround the production and use of critical materials, and to focus the government's resources on mitigation of critical materials supply risks. The Subcommittee, initially chartered in 2010, was rechartered in April 2016. According to its charter, the Subcommittee is to facilitate a strong, coordinated effort across federal agencies to identify and address important policy implications arising from critical and strategic mineral supply issues. The charter identifies the following federal agencies and Executive Office of the President organizations as members of the Subcommittee.

Federal agencies
Department of Agriculture
Department of Commerce
Department of Defense
Department of Education
Department of Energy (co-chair)
Department of Homeland Security
Department of the Interior (co-chair)
Department of Justice
Department of Labor

Department of State
Department of the Treasury
Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation
Executive Office of the President organizations
Council on Environmental Quality
National Economic Council
National Security Council
Office of Management and Budget
Office of Science and Technology Policy (co-chair)
Office of the U.S. Trade Representative

Although the Subcommittee was not chartered to implement the 1980 Act, many of the functions identified in its charter are similar to policies outlined in the act. Examples of functions identified by the Subcommittee charter that are similar to policies in the act include

- implementing and, as necessary, updating the methodology developed cooperatively by Subcommittee member agencies for dynamically assessing mineral criticality and for signaling emerging critical or strategic minerals;
- reviewing and analyzing domestic and global policies that affect the supply of critical and strategic minerals, assessing their implications on U.S. manufacturing, and evaluating potential strategies for risk mitigation, as needed;
- identifying cross-agency opportunities in research and development and in education and training for addressing critical and strategic minerals across the life cycle spectrum, including extraction, processing, and recycling; and
- considering and offering recommendations for enhanced U.S. minerals data collection and economic analysis.

The Subcommittee meets several times per year at varying intervals, according to OSTP officials. Subcommittee meeting agendas are developed by the co-chairs with input from member agencies. According to OSTP and DOE officials, agency participation on the Subcommittee is voluntary.

Federal Agencies Primarily Focus on Risk Assessment and Research but Also Conduct a Range of Other Activities Related to Critical Materials Supply

Federal agencies are primarily focused on two areas of activity related to critical materials supply—assessing risk and supporting research—in addition to conducting a range of other activities. Agencies' other critical materials activities include stockpiling or producing materials and reviewing and approving resource extraction projects, among other efforts.

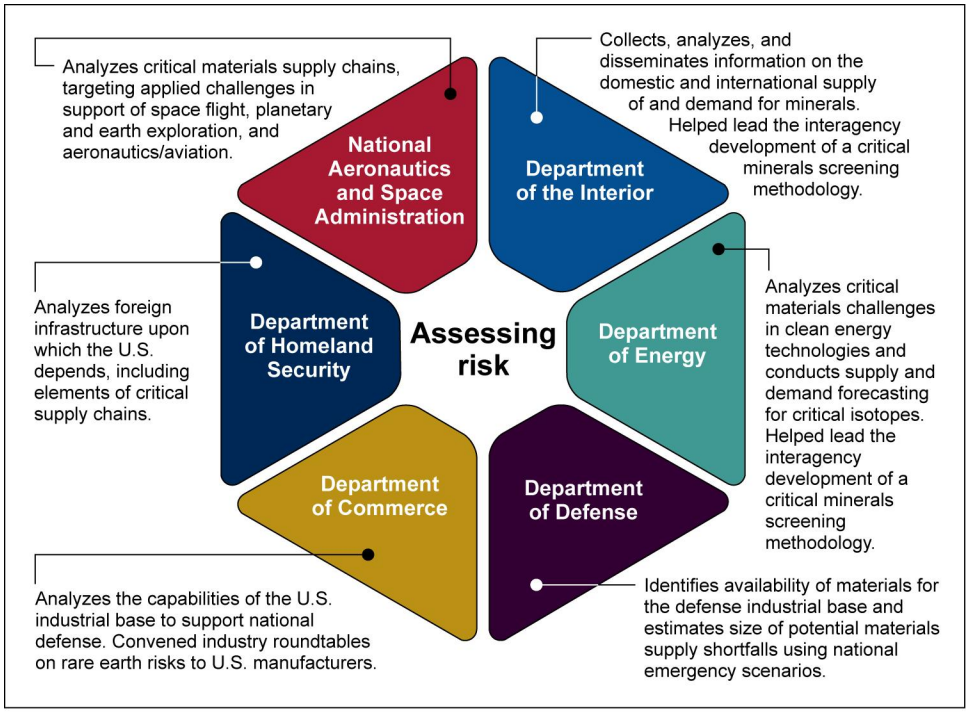
Federal Activities Related to Critical Materials Supply Are Primarily Focused on Assessing Risk and Supporting Research

Agencies' critical materials supply activities focus on two primary areas—assessing risk and supporting research.

Assessing Risk

Federal agencies engage in a variety of activities to identify and assess risks related to critical materials supply. These activities include collecting and disseminating information on material supply and demand, conducting targeted analyses of specific sectors, and conducting broader assessments to determine which materials are critical for the U.S. economy or security. Commerce, DOD, DOE, DHS, Interior, and NASA conduct activities to identify and assess critical materials supply risk, as shown in figure 3.

Figure 3: Federal Agencies' Activities to Identify and Assess Critical Materials Supply Risk



Source: GAO analysis of information and documents collected from agency officials. | GAO-16-699

The following federal agencies conduct activities to identify and assess critical materials supply risk:

- **Interior.** Interior's U.S. Geological Survey's (USGS) National Minerals Information Center develops and provides statistics and information on the worldwide production, consumption, and flow of minerals and materials essential to the United States economy and national security. The center, established in 1996 under USGS upon the dissolution of the U.S. Bureau of Mines, produces a number of reports, including the annual *Minerals Yearbook* and the *Mineral Commodity Summaries*. The *Minerals Yearbook* is an annual publication that provides statistical data on approximately 90 commodities. It also includes data from over 175 countries on mineral production and trade, among other things. The *Mineral Commodity Summaries* is based on the data reported in the yearbook and includes data over a 5-year period. The annual summary includes similar historical data as reported in the

Minerals Yearbook, as well as production estimates from the current reporting year. Interior's BLM also collects information related to mineral resources. Although BLM generally relies on data provided by USGS, it periodically issues mineral potential reports to assess the mineral resource occurrence and development potential on land related to particular mining applications or projects. For example, in 2012 BLM issued an assessment of the mineral potential of public lands located within a proposed solar energy zone in New Mexico. As part of the assessment, BLM evaluated whether certain minerals produced in New Mexico and that are classified as strategic and critical minerals for national defense purposes, including bismuth, copper, fluorspar, manganese, tungsten, vanadium, and zinc, were found within the proposed solar energy zone.

- **DOE.** As part of its efforts to advance a clean energy economy, DOE conducted two criticality assessments on materials important to clean energy applications, such as wind turbines, electric vehicles, photovoltaic cells, and fluorescent lighting. DOE's first assessment, published in a 2010 *Critical Materials Strategy*, evaluated 14 materials and identified 10, including 7 rare earth materials, as critical or near critical over the short or medium terms. DOE's second assessment, published in a 2011 *Critical Materials Strategy*, assessed 16 materials and identified 10 of them as critical or near critical over the short or medium terms.[13] As part of its 2015 *Quadrennial Technology Review*, DOE also published a critical materials technology assessment that reported on major trends driving future material criticality for selected clean energy applications.[14] Additionally, DOE manages the Isotope Development and Production for Research and Applications program (Isotope Program) through which it produces and distributes radioactive and stable isotopes that are in short supply but are critical for either federal government or U.S. commercial

[13]See app. II for a comparison of the results of selected U.S. critical materials assessments.

[14]DOE's 2015 *Quadrennial Technology Review* examines the status of the science and technology of the U.S. energy system, as well as the research, development, demonstration, and deployment opportunities to advance energy science and technologies. Department of Energy, *Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities* (Washington, D.C.: September 2015).

use.[15] As part of the Isotope Program, DOE has a process to identify high-priority isotopes by monitoring long-term changes in demand within the isotope community that could affect isotope availability.

- **DOD.** Three DOD organizations have related responsibilities for managing risks from DOD's use of "critical" and "strategic and critical" materials: the Defense Logistics Agency-Strategic Materials (DLA-Strategic Materials), the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, and the Strategic Materials Protection Board.[16] DOD periodically issues two reports analyzing critical materials for defense needs according to statutory definitions of "critical" and "strategic and critical" materials. The *Annual Industrial Capabilities Report to Congress* provides analyses of sectors of the defense industrial base, such as aircraft and ground vehicles. The biennial *Strategic and Critical Materials Report on Stockpile Requirements* summarizes DLA-Strategic Materials' analyses of materials for the National Defense Stockpile.[17] According to DLA-Strategic Materials officials and an official with DOE's Oak Ridge National Laboratory, DLA-Strategic Materials also collaborated with DOE's Oak Ridge National Laboratory and a private company to develop the Strategic Material Analysis and Reporting Topography software tool, which is a computer-based supply chain mapping tool that can visually represent the supply chain for any number of materials.

[15]Isotopes are varieties of a given chemical element with the same number of protons but different numbers of neutrons. See the following reports for more information on GAO's past reviews of the Isotope Program: GAO, *Managing Critical Isotopes: Stewardship of Lithium-7 Is Needed to Ensure a Stable Supply*, GAO-13-716 (Washington, D.C.: Sept. 19, 2013); *Managing Critical Isotopes: DOE's Isotope Program Needs Better Planning for Setting Prices and Managing Production Risks*, GAO-12-591 (Washington, D.C.: May 23, 2012); and *Managing Critical Isotopes: Weaknesses in DOE's Management of Helium-3 Delayed the Federal Response to a Critical Supply Shortage*, GAO-11-472 (Washington, D.C.: May 12, 2011).

[16]For more information on how DOD analyzes critical materials within the specific context of rare earth materials, see GAO, *Rare Earth Materials: Developing a Comprehensive Approach Could Help DOD Better Manage National Security Risks in the Supply Chain*, GAO-16-161 (Washington, D.C.: Feb. 11, 2016).

[17]See app. II for a comparison of the results of selected U.S. critical materials assessments.

- **Commerce.** The department's Bureau of Industry and Security is responsible for analyzing the capabilities of the U.S. industrial base to support national defense. The bureau conducted a strategic materials survey to evaluate the supply chains associated with several materials considered important to defense programs and systems. The resulting data set and report are intended to assist DOD in developing planning and acquisition strategies designed to ensure the availability of materials critical to defense missions. In addition to its work supporting DOD, Commerce's International Trade Administration (ITA) convened two roundtables of industry and government participants to gather information on critical materials issues that may affect U.S. manufacturers and the competitiveness of U.S. industry. ITA's Office of Materials Industries hosted the first roundtable in 2009 to discuss issues related to access to rare earth materials that could affect important end uses, such as clean energy technologies. ITA convened the second roundtable in 2012, in cooperation with the Subcommittee, to identify the materials, technologies, and supply chains that should be prioritized to develop an interagency assessment of critical minerals.
- **DHS.** Under the Critical Foreign Dependency Initiative, DHS identifies critical foreign infrastructure that, if disrupted, could significantly affect U.S. public health, economic vitality, industrial capability, or security. The initiative is a collaborative effort co-led by DHS and State, with other relevant agencies. According to a DHS official, such infrastructure can include mines or other production facilities that are foreign sources of critical materials, as determined by an interagency process. This assessment process involves both public and private sector partners responsible for critical infrastructure and key resources. Also, the DHS Science and Technology Directorate funded academic research examining the extent to which critical chemicals in the U.S. supply chain are being produced in foreign countries.
- **NASA.** Agency officials stated that NASA is analyzing its supply chains for materials that it deems essential to its mission. According to a 2012 presentation on its approach to critical materials management, NASA's research and evaluation efforts target applied challenges in support of spaceflight, planetary and earth exploration, and aeronautics/aviation. NASA officials stated

that many of the materials that the agency relies on are commonly used by both NASA and DOD and can include elements such as tungsten, chromium, and nickel that are used in making alloys.[18] In the view of one NASA official we spoke with, these actions are aligned with the 2010 National Space Policy, which called for agencies to engage with industrial partners to improve processes and effectively manage supply chains, among other things.[19]

In addition to these six agencies' efforts, the Subcommittee has also coordinated an interagency effort to develop a methodology to identify potentially critical materials for the U.S. economy or security, which it has described as an early warning screening. OSTP, DOE, and Interior's USGS, through their participation as co-chairs of the Subcommittee, have led the effort to develop the early warning screening, with other Subcommittee members providing key input. In March 2016, the Subcommittee published a criticality assessment in which it reported on its progress in developing a screening methodology for critical minerals and the results of the initial application of this methodology.[20] The methodology described in the Subcommittee's report is the first step in a two-stage process to identify which minerals pose a risk of becoming critical. The Subcommittee screened 78 mineral resources using its methodology and identified 17 minerals as potentially critical. According to the March 2016 report, the next steps for the second stage of the process include (1) developing a prioritized list of a subset of the 17 potentially critical minerals for in-depth investigation, (2) developing

[18]Tungsten-rhenium ingot was one of the materials DOD identified as having a shortfall in its 2015 analysis of materials for the National Defense Stockpile. See app. II for more information.

[19]Executive Office of the President, *National Space Policy of the United States of America* (Washington, D.C.: June 28, 2010). NASA's analysis of its supply chains is also guided by the 2012 *National Strategy for Global Supply Chain Security*, see Executive Office of the President, *National Strategy for Global Supply Chain Security* (Washington, D.C.: Jan. 23, 2012).

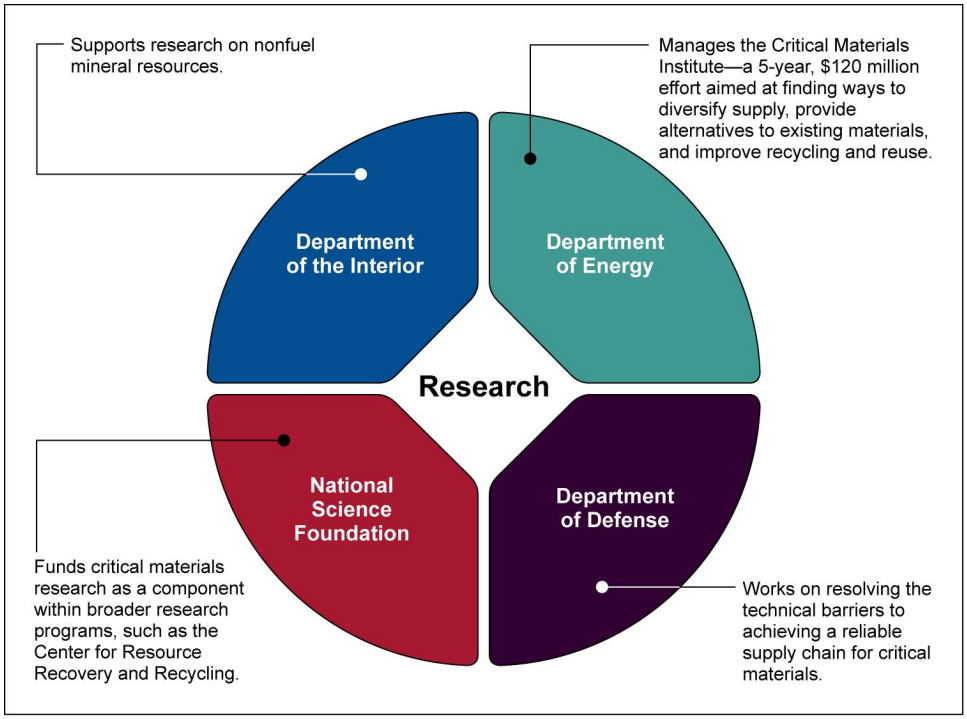
[20]National Science and Technology Council, Subcommittee on Critical and Strategic Mineral Supply Chains of the Committee on Environment, Natural Resources, and Sustainability, *Assessment of Critical Minerals: Screening Methodology and Initial Application* (Washington, D.C.: March 2016).

individual project plans for those minerals for further study, and (3) carrying out the targeted studies in the next annual cycle.[21]

Supporting Research

Federal agencies support research that encompasses a range of approaches to address critical materials supply issues, including projects to (1) discover or develop substitutes that can duplicate the unique properties of critical materials, (2) develop new approaches or technologies that minimize the use of critical materials, and (3) develop new approaches or technologies to increase the efficiency of domestic production of critical materials or enable the recycling of specific materials. Figure 4 shows federal activities related to critical materials research.

Figure 4: Federal Agencies' Research Activities Related to Critical Materials Supply



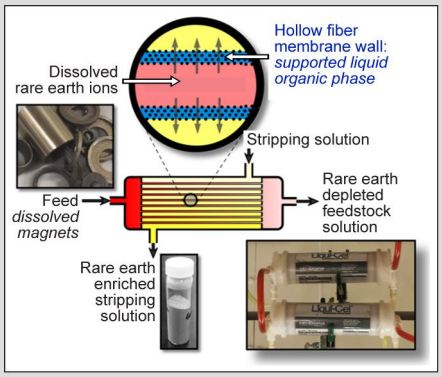
Source: GAO analysis of information and documents collected from agency officials. | GAO-16-699

[21]See app. II for a comparison of the results of selected U.S. critical materials assessments.

The following federal agencies support research related to critical materials supply:

- **DOE.** The Critical Materials Institute (CMI), based at DOE's Ames Laboratory in Iowa, is a 5-year, $120 million public-private partnership, with partners from other national laboratories, universities, and industry. CMI began operations in June 2013, and its mission is to help ensure supply chains of materials critical to clean energy technologies (see sidebar).

CMI Research Projects



Source: Department of Energy.

According to the Department of Energy, as of May 1, 2016, Critical Materials Institute (CMI) research projects have resulted in 42 invention disclosures, 17 patent applications and 1 licensed technology. One example is the development of a membrane solvent extraction system that aids in the recycling, recovery, and extraction of rare earth materials. The system was developed by researchers at Oak Ridge and Idaho National Laboratories and has been licensed to a U.S. company. According to CMI researchers, the recycling of critical materials from electronic waste has been limited by processing technologies that are inefficient, costly, and environmentally hazardous. The researchers report that this new simplified process, shown in the figure above, eliminates many of these limitations. The technology uses a combination of hollow fiber membranes, organic solvents, and neutral extractants to selectively recover rare earth elements such as neodymium, dysprosium, and praseodymium. In laboratory testing, the membrane extraction system demonstrated the potential to recover more than 90 percent of neodymium, dysprosium, and praseodymium in a highly pure form from scrap neodymium-based magnets. The licensing company has indicated that it intends to apply the technology to recover rare earth elements from old electronics and from its mining claims in the United States.

Source: GAO summary of Department of Energy information. | GAO-16-699

CMI's research efforts focus on diversifying the supply of materials, developing substitute materials, and improving the efficiency of material use and reducing waste, among other efforts. DOE officials told us that CMI collaborates informally with other DOE offices with efforts related to critical materials research. For example, CMI collaborated with DOE's Advanced Research Projects Agency-Energy, which awarded $40.8 million to 14 projects in the Rare Earth Alternatives in Critical Technologies program to support early stage development of rare earth-free magnetic materials, novel motor designs that reduce or eliminate the need for rare earth materials, and High Temperature Superconductor wires for large-scale wind generators with no rare earth magnets. Another example DOE officials cited was collaboration with the DOE Office of Fossil Energy's National Energy Technology Laboratory to fund research on the recovery of rare earth elements from coal and coal by-products.

- **DOD.** DOD funds critical materials research both through component agencies that support the entire department and through the Army, Navy, and Air Force research organizations. DOD's research approach to mitigating the risk associated with the supply of critical materials used in weapon components has varied, but according to officials, critical materials have been studied as part of meeting mission requirements to increase performance and capabilities and to reduce costs of DOD technologies. For example, the Army Research Laboratory collaborated with academic and industrial partners to explore how to resolve the technical barriers to achieving a reliable domestic supply chain for certain rare earth materials.
- **NSF.** In fiscal year 2013, NSF started an initiative to encourage and foster research in sustainable chemistry, engineering, and materials to address the interrelated challenges of sustainable supply, engineering, production, and use of chemicals and materials. Examples of research topics in this area include replacing rare, expensive, or toxic materials with earth-abundant, inexpensive, and benign materials; discovering new techniques to facilitate recycling and producing valuable materials; and developing and characterizing low cost, sustainable, and scalable-manufactured materials with improved properties. NSF also supports the Center for Resource Recovery and Recycling, which addresses challenges related to materials recovery and

recycling.[22] Researchers from the center developed a method of extracting rare earth elements from drive units and motors of discarded electric and hybrid vehicles. The goal of that work is to recycle rare earth materials that would otherwise be lost and create an alternative source of these materials.

- **Interior.** The department's USGS supports research on nonfuel mineral resources. According to a senior USGS official, a priority area in this research is identifying and characterizing critical mineral resources through activities such as mineral resource assessments, mineral deposit models, and remote sensing exploration techniques. According to the official, the focus of these activities is on domestic mineral resources.

Agencies Conduct a Range of Other Activities Related to Critical Materials Supply

In addition to activities in the primary areas described above, federal agencies conduct a wide range of other activities related to the supply of critical materials.

- **Addressing trade issues.** USTR plays a key role in the federal government's efforts to address trade issues. While USTR does not have a specific program or focus area related to critical materials, the agency has worked, in collaboration with other federal agencies and international partners, to address trade issues affecting materials that are critical for a range of industries. For example, USTR led the federal government's World Trade Organization (WTO) dispute against China's export restrictions on rare earth materials, tungsten, and molybdenum, resulting in a finding that the export restrictions were inconsistent with China's WTO obligations, and continues to monitor China's actions to ensure compliance with the WTO decision.[23] According to USTR

[22]The Center for Resource Recovery and Recycling is supported through NSF's Industry/University Cooperative Research Centers Program, which was initiated in 1973 to develop long-term partnerships among industry, academia, and government.

[23]In March 2012, the United States requested consultations with China through the WTO with respect to China's export restrictions—including export duties and export quotas—on rare earth materials, tungsten, and molybdenum. Other countries joined the United States in the dispute. In March 2014, a WTO dispute settlement panel found that China's export restrictions were inconsistent with its WTO obligations, and in August 2014, the WTO appellate body affirmed the ruling. In May 2015, China announced that it had removed the export restrictions in question.

officials, the agency also engages in activities to create more transparency about export restraints, such as maintaining ongoing trade dialogues on raw materials and working with other countries within the Organisation for Economic Co-operation and Development to create an inventory of trade restrictions related to raw materials and energy.[24] In addition to USTR's efforts, the Subcommittee has also played a role in addressing trade issues. For example, in 2013 the Subcommittee requested changes to the Harmonized Tariff Schedule of the United States that according to OSTP officials, provided more granular data on U.S. imports of rare earth materials, among other changes.[25] Similarly, in 2014 the Subcommittee submitted a request for additional changes to the Harmonized Tariff Schedule to provide more granular data on U.S. imports of permanent magnets, among other changes.

- **Coordinating internationally.** Federal agencies have coordinated with international partners on critical materials issues through different forums. For example, the EU-US-Japan Trilateral Conference on Critical Materials—which is jointly organized by the European Commission; DOE; and the Japanese Ministry of Economy, Trade, and Industry (METI)—has taken place for 5 consecutive years to exchange information on recent developments in critical materials research and development. According to a DOE official, the first few conferences began with high-level policy discussions, but they have become focused more on researcher-to-researcher exchanges about technology efforts. Another example is the Transatlantic Economic Council, which, in 2011, agreed to launch a cooperative platform on raw materials focusing on five areas: (1) trade cooperation; (2) raw materials

[24]The Organisation for Economic Co-operation and Development is an organization of 34 countries founded in 1961. Its mission is to promote policies that will improve the economic and social well-being of people around the world, and it provides a forum in which governments can work together to share experiences and seek solutions to common problems.

[25]The Harmonized Tariff Schedule of the United States, published and maintained by the United States International Trade Commission, provides the legal basis for the classification of every product that enters the United States and the corresponding tariff rate the importer must pay for each product. All goods imported into the United States are classified according to the schedule. Prior to the changes requested by the Subcommittee, there were not separate codes for rare earth elements; however, the Subcommittee's request resulted in separate codes for lanthanum, cerium, praseodymium, and neodymium.

data, flows, and information sharing; (3) resource efficiency and recycling; (4) research and development on raw material substitution and reduction; and (5) waste shipment. According to a State Department official, individual federal agencies have led U.S. efforts in each focus area based on their individual missions. For example, USTR led efforts in trade cooperation; USGS led efforts in raw materials data; and DOE led efforts in research and development and recycling, with EPA's assistance on recycling. Other examples of international coordination that were described to us by federal agency officials include annual reviews of strategic stockpile issues between the United States, Japan, and the Republic of Korea, and U.S. participation in the G7 Alliance on Resource Efficiency.[26]

- **Reviewing and approving mining projects.** BLM and the U.S. Forest Service oversee the extraction of minerals on federal land.[27] BLM and Forest Service officials said that their agencies do not consider mineral criticality in their administration of mining projects. When a mining operator submits a plan for a new mine on federal land, either BLM or the Forest Service analyzes the potential impact of the proposed mine on the environment, human health, and cultural resources by conducting an analysis under the National Environmental Policy Act. The National Environmental Policy Act requires federal agencies to evaluate the likely environmental effects of a proposed project using an environmental assessment or, if the project is likely to significantly affect the environment, a more detailed environmental impact statement.[28] From fiscal years 2010 through 2014, BLM and the Forest Service approved 68 hardrock mine plans, 2 of which were

[26]According to the Council on Foreign Relations, the Group of Seven (G7) is an informal bloc of industrialized democracies—the United States, Canada, France, Germany, Italy, Japan, and the United Kingdom—that meets annually to discuss issues such as global economic governance, international security, and energy policy. The G7 Alliance on Resource Efficiency was established in June 2015 to serve as a forum to share knowledge, create information networks across G7 countries, and encourage collaboration with large and small business and relevant stakeholders.

[27]The 193 million acres of public land managed by the Forest Service as national forests and grasslands are collectively known as the National Forest System. These lands are located in 44 states, Puerto Rico, and the Virgin Islands and make up about 9 percent of the United States' total land area.

[28]42 U.S.C. §§ 4321-4347 (2016).

for materials that have been identified as critical by DOD—magnesium and manganese.

- **Stockpiling or producing materials.** DLA-Strategic Materials is responsible for storing select materials in the National Defense Stockpile to mitigate potential shortages based on certain national emergency planning assumptions. Based on the biennial analyses described previously, DLA-Strategic Materials makes recommendations to acquire specific forms and amounts of materials and then maintains these materials in the stockpile.[29] Additionally, in 2005, DOD invested in a public-private partnership with the leading U.S. beryllium producer to build a new $90.4 million primary beryllium facility in Ohio to ensure current and future availability of high-quality domestic beryllium to meet critical defense needs.[30] The federal government has also been extensively involved in the production, storage, and use of helium since the early part of the 20th century.[31] BLM is responsible for managing the federal helium program, including an underground reservoir for the storage of federally and privately owned helium.[32] The reserve provides a supply of federal helium to such agencies as DOD, DOE, and NASA that rely on the rare gas for research

[29]DLA-Strategic Materials is also beginning efforts to add recycled materials to the stockpile. For more information on how DOD recovers materials from electronic waste, see GAO, *Electronic Waste: DOD Is Recovering Materials, but Several Factors May Hinder Near-Term Expansion of These Efforts*, GAO-16-576 (Washington, D.C.: June 20, 2016).

[30]According to a January 2013 USGS mineral commodity summary, DOD engaged in this partnership under the authority of the Defense Production Act of 1950, 50 U.S.C. §§ 4501-4568 (2016). Beryllium is highly desired in many sectors, including aerospace, defense, nuclear, medical equipment, and telecommunications infrastructure. Beryllium-copper alloys are strong, are nonmagnetic, resist corrosion, and are good conductors of electricity and heat.

[31]Helium in this report refers to helium-4, the most abundant naturally occurring helium isotope. Helium is an important nonrenewable natural resource with a variety of important uses, including national security applications, scientific research, medical instruments, and manufacturing.

[32]GAO, *Bureau of Land Management: More Information Needed to Implement the Helium Stewardship Act of 2013*, GAO-15-394 (Washington, D.C.: Apr. 16, 2015), and *Helium Program: Urgent Issues Facing BLM's Storage and Sale of Helium Reserves*, GAO-13-351T (Washington, D.C.: Feb. 14, 2013).

and medical and national defense applications.[33] Further, under DOE's Isotope Program, DOE produces and distributes radioactive and stable isotopes in short supply for commercial or federal needs. According to DOE officials, the federal government is uniquely suited to produce certain isotopes as production may require recycled or reused national security-related source materials, big accelerators, and research facilities that are only available within the federal government, or it is not profitable for industry to provide the small amounts of isotopes needed for research applications.

- **Promoting technical education and workforce development.** DOE's CMI offers a variety of educational opportunities through several partners, including the Colorado School of Mines, Iowa State University, and the University of Tennessee, Knoxville. For example, in November 2015, CMI announced the development of a three-credit on-line course, offered through Iowa State University for the 2016 spring semester, focused on rare earth materials. According to CMI's announcement, the course covers a wide range of topics related to rare earth materials, including extraction, separation, preparation and purification; properties related to these materials; and other topics. Additionally, students at the University of Tennessee, Knoxville, have been evaluating conceptual processes for recovery of rare earths from unconventional resources. CMI also provides science and engineering outreach to elementary and high school students through its partnership with the Colorado School of Mines. As described above, NSF supports critical materials research. According to NSF's research proposal and award policies and procedures guidance, one of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at NSF awardee organizations. NSF supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning. NSF expects research proposals to discuss the broader impacts of proposed activities, such as improved STEM education and educator

[33]The Helium Stewardship Act of 2013 calls for the privatization of the federal helium reserve by 2021. See GAO-15-394.

development, and development of a diverse, globally competitive STEM workforce.

- **Recycling and sustainable materials management.** Through its Sustainable Materials Management program, EPA engages with public and private stakeholders to advance the productive and sustainable use of materials across their life cycles. According to EPA officials, the agency is in a unique position to lead in the effort of getting industry involved in addressing critical materials consumption. In 2009, EPA published a report outlining measures it could take to promote efforts to manage materials and products on a life cycle basis with a goal of sustainable materials use.[34] Additionally, EPA co-chaired an interagency task force on electronics stewardship, which produced a 2011 *National Strategy for Electronics Stewardship* that included goals and recommendations, among other things, to improve the ability to recover and market valuable materials from used electronics, especially precious metals and rare earth materials.[35]
- **Supporting commercialization of new technologies.** The National Institute of Standards and Technology provides support for industrial adoption of rare earth materials substitutes by providing material measurement science and developing data and models. For example, the institute provides standard reference materials that measure the intensity of magnetism that can be induced by magnetic fields, which is of interest to the permanent magnet industry—a major user of rare earth materials. Additionally, the Materials Genome Initiative—under the National Science and Technology Council's Subcommittee on the Materials Genome Initiative—is a multiagency initiative designed to discover, develop, and manufacture the next generation of materials to meet national needs.

[34]Environmental Protection Agency, *Sustainable Materials Management: The Road Ahead*, EPA530-R-09-009 (Washington, D.C.: June 2009).

[35]Interagency Task Force on Electronics Stewardship, *National Strategy for Electronics Stewardship* (Washington, D.C.: July 20, 2011).

The EU and Japan Collaborate with Stakeholders across a Wide Range of Industrial Sectors, and Canada Focuses on Resource Production

The EU, Japan, and Canada have different approaches to address critical materials supply issues. According to the EU policy documents that we reviewed, the EU has a collaborative, economy-wide approach that incorporates sustainability. According to the government officials that we interviewed, Japan's approach focuses on securing access to foreign sources and conducting materials science research to bolster industrial competitiveness. According to government reports that we reviewed, Canada encourages resource production by providing tax incentives and improving the efficiency of regulatory reviews.

The EU Has a Collaborative, Economy-Wide Approach That Incorporates Sustainability

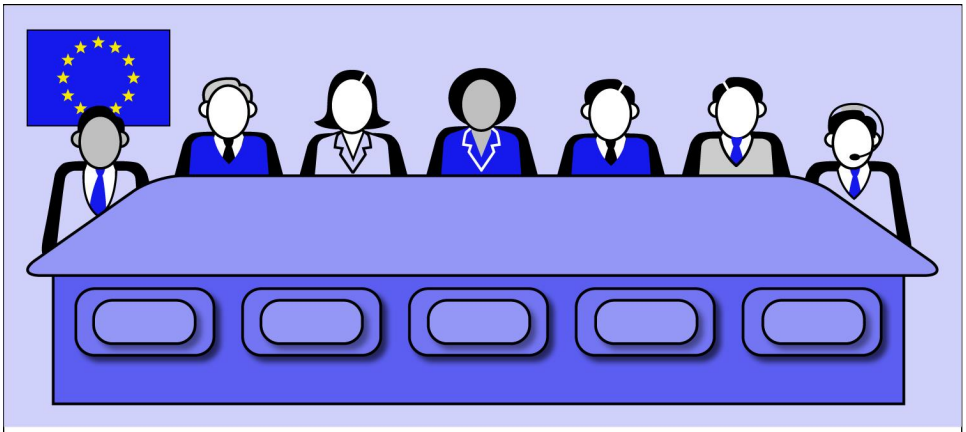
The EU has developed a collaborative, economy-wide approach to addressing the supply of critical materials that incorporates a focus on developing a more sustainable and resource-efficient economy. The EU's Raw Materials Initiative, which was outlined by the European Commission in its 2008 communication to the European Parliament and Council,[36] has three pillars: (1) ensure access to raw materials from international markets under the same conditions as other industrial competitors, (2) set the right framework conditions within the EU in order to foster a sustainable supply of raw materials from European sources, and (3) boost overall resource efficiency and promote recycling to reduce the EU's consumption of primary raw materials and decrease the relative import dependence.[37] The Raw Materials Initiative is implemented, in part, through the European Innovation Partnership on Raw Materials (Partnership)—a stakeholder platform that brings together EU countries, companies, researchers, and nongovernmental organizations to promote innovation in the raw materials sector. According to EU officials, the Partnership has defined 95 actions to be carried out both within the EU

[36]The EU is governed by several institutions. The European Commission is the EU's executive body. It implements and manages EU policies and enforces European law, among other things. The European Council acts as the strategic guide for EU policy. It is composed of the heads of state or government of the EU's member states, the European Council President, and the President of the European Commission. The European Parliament represents the citizens of the EU. It consists of 751 members who are directly elected for 5-year terms.

[37]Commission of the European Communities, *Communication from the Commission to the European Parliament and the Council: The Raw Materials Initiative—Meeting Our Critical Needs for Growth and Jobs in Europe* (Brussels: November 2008).

and internationally, in order to secure the EU supply of raw materials via innovation. In 2014, an independent expert group studied the Partnership model and found that it has been a useful vehicle in bringing partners together with a view to align priorities, leverage investments, and form future partnerships.[38] The group's report stated that European innovation partnerships have generally been good in ensuring extensive participation of all relevant stakeholders, and they have also created effective channels for the interested actors to become engaged in the partnerships, including through invitations for commitments. Figure 5 shows key information about the Partnership.

Figure 5: European Innovation Partnership on Raw Materials



- Led by a steering group with 36 key stakeholders across government, academia, and industry.
- Steering group first met in February 2013.
- Selected targets to be achieved by 2020:
  - up to 10 pilot programs on exploration, mining, processing, and recycling for innovative production of raw materials;
  - substitutes for at least three applications of critical and scarce raw materials; and
  - network of research, education, and training centers on sustainable raw materials management.

Source: GAO summary of information on the European Innovation Partnership on Raw Materials. | GAO-16-699

[38]European Commission, *Outriders for European Competitiveness - European Innovation Partnerships (EIPs) as a Tool for Systemic Change - Report of the Independent Expert Group,* 10.2777/6089 (Luxembourg: 2014).

According to EU officials, the majority of the Partnership's priorities have been reflected in Horizon 2020, the EU research and development funding program for 2014 to 2020.[39] Horizon 2020 has several broad pillars, one of which is climate action, environment, resource efficiency, and raw materials. According to a European industry association we interviewed, an example of efforts in this area involves trying to find ways to provide more supply for raw materials from the EU. Association officials told us that mining ventures tend to raise significant social opposition, which can diminish potential for getting projects under way. According to the officials, this aspect of the Horizon 2020 program tries to take a social approach to mining by using advanced technology to help address social opposition. This focus on public awareness is also an action area outlined in the Partnership's 2013 Strategic Implementation Plan. The action area is mostly industry led but is also supported by concerned stakeholders—communities, institutions, and regulatory bodies—at all levels. It aims to first increase public awareness of the benefits and potential costs of raw materials supply and then gain public acceptance and trust by improved communication and transparency, notably during the permitting process and the production cycle (i.e., exploration, mine operation, and after mining).

The Partnership states that it will play an important role in meeting the objectives of Resource Efficient Europe—an initiative under the Europe 2020 strategy that supports the shift toward a resource-efficient, low-carbon economy to achieve sustainable growth—by ensuring the sustainable supply of raw materials to the European economy.[40] This illustrates the connection within EU policy between the criticality of certain raw materials and the goal of shifting towards a more resource-efficient economy and sustainable development. This connection is also evident in the second and third pillars of the Raw Materials Initiative, listed above,

[39]European Commission, *Horizon 2020 in Brief, The EU Framework Programme for Research and Innovation* (Luxembourg: 2014).

[40]Europe 2020 is the EU's 10-year jobs and growth strategy. According to the European Commission's website, the initiative was launched in 2010 to create the conditions for smart, sustainable, and inclusive growth. Five targets have been agreed for the EU to achieve by the end of 2020: employment; research and development; climate/energy; education; social inclusion and poverty reduction. See Commission of the European Communities, *Communication from the Commission: Europe 2020, A Strategy for Smart, Sustainable and Inclusive Growth* (Brussels: March 2010).

which focus on sustainability and recycling. As stated in the European Commission's 2008 communication on the raw materials initiative, the EU views boosting overall resource efficiency as a key part of a path toward a secure supply of raw materials.

The Raw Materials Initiative also called for the EU to identify a common list of critical raw materials for the EU's economy. To develop this list of critical raw materials, the EU set up the Ad-Hoc Working Group on Defining Critical Raw Materials, which comprises experts across government, industry, and academia, as described in the Working Group's 2010 report.[41] The European Commission, with the Ad-Hoc Working Group, published its first criticality analysis for raw materials in 2010. In that analysis, 14 critical raw materials were identified from a candidate list of 41 nonenergy, nonagricultural materials. In 2013, the commission and the working group, in cooperation with a group of researchers, updated this work and analyzed 54 nonenergy, nonagricultural materials, identifying 20 of them as critical raw materials.[42] EU officials we interviewed stated that they believe that the list of critical materials is useful for prioritizing and identifying relevant research, raising awareness, fostering trade negotiations, and communicating with stakeholders, such as trade and industry groups. According to the officials, the list is also used to incentivize the European production of critical raw materials and facilitate the launching of new mining and recycling activities.

In addition to the Ad-Hoc Working Group on Defining Critical Raw Materials, which conducts official criticality analyses, there are a number of stakeholder organizations in the EU and in EU member states that support collaboration between industry, government and academia. Examples include the European Institute of Innovation and Technology Knowledge and Innovation Community on Raw Materials and a future Expert Network on Critical Raw Materials, which will be launched under Horizon 2020 by the European Commission.

[41]European Commission, *Critical Raw Materials for the EU* (Brussels: July 2010).

[42]European Commission, *Report on Critical Raw Materials for the EU* (Brussels: May 2014).

Japan Focuses on Securing Access to Foreign Sources and Conducting Materials Science Research to Bolster Industrial Competitiveness

According to a report on the raw materials strategies of industrialized countries, Japan's heavy dependence on metal and mineral imports has led it to focus on securing access to foreign sources of materials and exploring substitute materials through materials science research as a way to ensure its continued industrial competitiveness.[43] According to government officials we interviewed, Japan's METI sets policy for raw material supplies. Officials told us that METI has established a five pillar strategy for the supply of rare metals: (1) promoting initiatives to secure resources overseas, (2) promoting recycling and development of smelting technology, (3) developing resource-saving and substitute materials, (4) stockpiling rare metals, and (5) developing marine resources.

According to government officials we interviewed, the Japanese government, through the Japan Oil, Gas and Metals National Corporation (JOGMEC), secures access to critical materials by providing direct funding to exploration and development projects around the world. JOGMEC's efforts fit into METI's policy framework under four of the five pillars—it is not involved in developing resource-saving and substitute materials. JOGMEC officials said that a primary aspect of JOGMEC's critical materials supply efforts is to provide financial and other types of assistance, such as liability protection, to Japanese companies for overseas mineral exploration or development projects. For example, JOGMEC officials said that they can engage in joint venture exploration projects with foreign companies. If the exploration proves fruitful, JOGMEC officials said that they can transfer JOGMEC's contractual interest in a project to a Japanese company. The officials said that this type of assistance can help to insulate Japanese companies from the impact of price shocks in individual materials markets. JOGMEC is also involved in a seabed exploration project seeking to help verify the feasibility of collecting rare earth materials from the ocean floor.

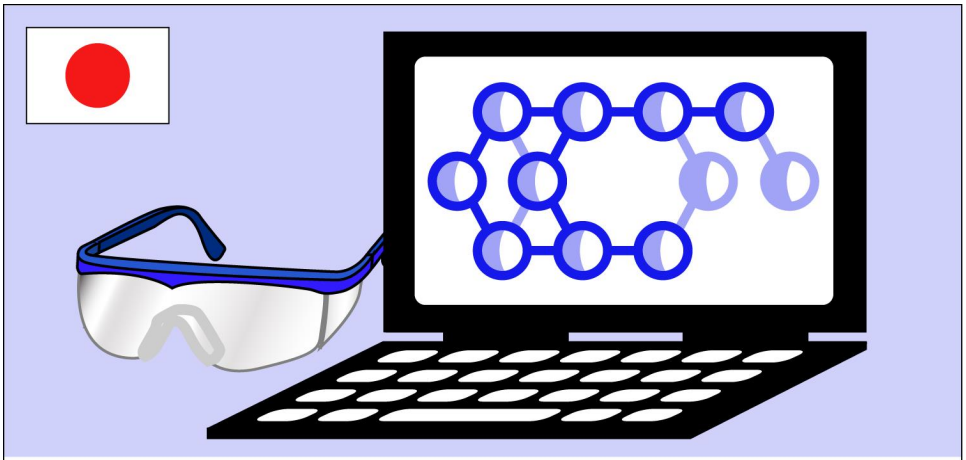
In addition, government officials told us that JOGMEC also engages with experts from across Japan's domestic industries, including recycling, automobile manufacturing, and telecommunications, to develop a material flow analysis that can pinpoint bottlenecks in the supply chain. JOGMEC started doing this kind of analysis more than a decade ago, more to

[43]German Federal Institute for Geosciences and Natural Resources, *Fragmentation or Cooperation in Global Resource Governance, a Comparative Analysis of the Raw Materials Strategies of the G20* (Berlin: March 2013).

identify bottlenecks in the supply chain than to provide material supply forecasts, officials told us. The officials told us that currently JOGMEC conducts material flow analyses for 42 materials. Officials also said that JOGMEC's critical materials efforts reflect a strong relationship between the government and the private sector in Japan. According to JOGMEC officials, investors tend to be more focused on new technologies, whereas the important role for the government is to take a medium-to-long-term view of the trends.

According to government officials, Japan has also been a leader in materials science research, and in 2007 the Japanese government began funding the Element Strategy, which was aimed at overcoming the limitation of natural resources by finding alternative materials for new and existing goods and processes. Under the Element Strategy, the Japanese government initiated a research collaboration between industry and academia wherein researchers worked to identify the unknown physical properties of all the elements in the periodic table in order to use each element to the fullest extent possible. In 2012, the Japanese government began a successor research and development program, which has been funded for 10 years. Figure 6 shows key information about Japan's Element Strategy.

Figure 6: Japan's Materials Science Element Strategy



- Initial industry and academic collaboration started in 2007.
- Research and development hub started in 2012 and funded at 2 billion yen (U.S. $19 million) per year, for 10 years.
- Based on inter-disciplinary and cross-sectoral collaboration.
- Governed by an inter-ministry board to facilitate coordination between the Ministry of Education, Sports, Culture, Science and Technology, which funds basic science research, and the Ministry of Economy, Trade and Industry, which funds applied science research.

Source: GAO summary of information on Japan's Element Strategy. | GAO-16-699

Canada Implements a Variety of Activities to Encourage Resource Production

Canada's focus on raw materials is to attract investment in its mining sector through tax incentives, research, and increased efficiency of regulatory reviews. Officials from Natural Resources Canada, the government ministry responsible for natural resources, energy, minerals and metals, forests, earth sciences, mapping, and remote sensing, stated that critical raw materials are important in the context of leveraging opportunities for economic development through the production and export of mineral products. According to a Canadian report to the United Nations (UN) Commission on Sustainable Development, Canada's mining sector plays an important part in the overall economic development of Canada.[44] According to that report, provincial governments are largely

[44]Canada, *National Reporting to the United Nations Commission on Sustainable Development (CSD) – 18/19 – Thematic Profile on Mining* (2011).

responsible for the exploration, development, and extraction of mineral resources and the construction, management, reclamation, and closeout of mine sites in their jurisdiction. The report also states that the Canadian federal government's responsibilities mainly pertain to international affairs, trade, and investment, including development assistance; fiscal and monetary policy; science and technology; and regulation of all activities related to mineral development in the territory of Nunavut. According to officials from Natural Resources Canada, the Canadian federal, provincial, and territorial governments share responsibilities for the protection of the environment, and proposed mine developments. Projects usually require separate federal and provincial environmental impact assessments and regulatory approvals.

Canada has taken a number of actions at both the federal and provincial levels to encourage investment in the mining sector, according to officials from Natural Resources Canada. According to officials we interviewed and reports we reviewed, tax incentives are a way the Canadian government encourages investment in the mining sector. According to officials from Natural Resources Canada, junior mining companies have no regular source of income and often have difficulty raising capital to finance their exploration and development activities. According to officials from Natural Resources Canada, Canada's flow-through share (FTS) mechanism allows principal business corporations, particularly junior mining companies, to obtain equity financing for mineral exploration and development in Canada, whereby a mineral exploration or mining company can transfer or flow-through the tax deductions arising from its eligible exploration expenses to the FTS investors, giving them the benefit. In addition, investors can receive an additional 15 percent Mineral Exploration Tax Credit (METC) for qualifying surface or above-surface exploration expenditures. According to information from the Natural Resources Canada website, for the individual investors, the advantages of investing in an FTS can be that they (1) receive a 100 percent tax deduction for the amount of money they invested in the shares, plus the 15 percent METC in the case of an eligible expense, and (2) may see the value of their investment appreciate in the event of successful exploration. According to the report to the UN Commission on Sustainable Development, a number of provinces also have a tax credit that harmonizes with the federal package, which makes individual investors' net costs of FTS investment less than half of their initial amounts.

Another example of Canada's investment in the mining sector is through its research investments. According to officials from Natural Resources

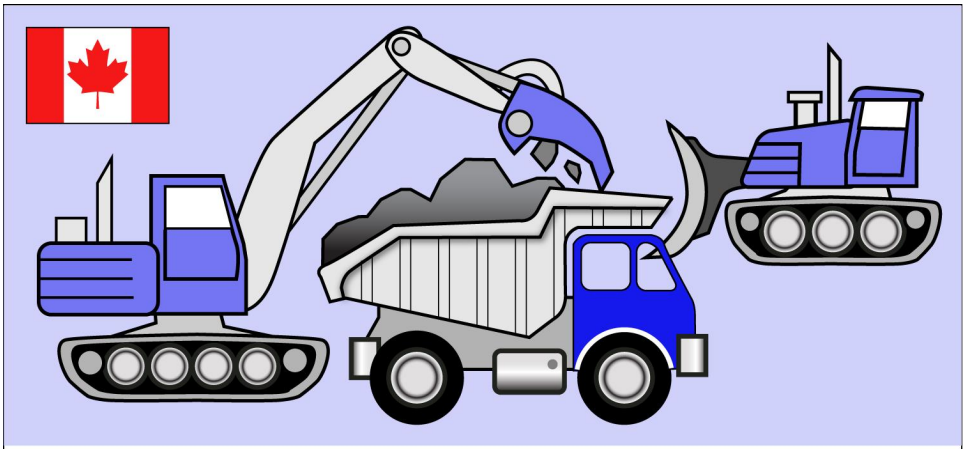
Canada, Canada invested C$100 million (U.S. $78 million) over 7 years (2013 through 2020) in the Geo-mapping for Energy and Minerals program to develop new energy and minerals resources and promote responsible land development. Officials told us that Canada also dedicated C$23 million (U.S. $18 million) over 5 years (starting in 2015-2016), to stimulate the technological innovation needed to separate and develop rare earth elements and chromite.

In addition to providing financial incentives for investing in the mining industry, the Canadian government has also focused on improving the efficiency of regulatory reviews of mining and other major projects. In 2007, the Canadian government launched the Major Projects Management Office (MPMO) Initiative to improve the effectiveness and efficiency of the federal regulatory review process, while ensuring careful consideration of environmental protection, consultation obligations, and industry competitiveness. According to a 2012 report from Natural Resources Canada on its evaluation of the MPMO Initiative,[45] there are eight participating departments and agencies that have agreed to implement the initiative both individually and in collaboration: the Aboriginal Affairs and Northern Development Canada, the Canadian Environmental Assessment Agency, Fisheries and Oceans Canada, Environment Canada, Transport Canada, the Canadian Nuclear Safety Commission, the National Energy Board, and Natural Resources Canada. The report states that through the initiative, the MPMO was established to conduct a range of activities that according to Natural Resources Canada officials, were intended to improve the accountability, transparency, timeliness, and predictability of the federal regulatory review process for major resource projects. The report further states that the mandate of the MPMO is to provide (1) major project management and coordination and (2) policy leadership, including problem-solving of short- to medium-term issues. In the area of project management and coordination, the MPMO's role includes coordinating the development of project agreements that include target timelines, ongoing project and performance monitoring, tracking and reporting, and administering the MPMO Tracker—a publicly accessible web-based monitoring system for major resource projects that can be updated in real time.

[45]Natural Resources Canada, *Evaluation of the Major Projects Management Office Initiative* (2012).

The 2012 evaluation of the MPMO Initiative by the Canadian government covered a number of issues, including the achievement of expected outcomes and demonstration of the efficiency and economy of the permitting process for mining projects. According to the report on the evaluation, the Canadian government found that the integration and federal coordination of environmental assessments and regulatory reviews increased under the initiative. In addition, as noted in the report, the evaluation also found that transparency and accountability of the federal regulatory process within the Canadian government increased significantly through the initiative. According to the evaluation, the Canadian government timelines were viewed by internal and external stakeholders to be improving because of increased capacity and improved integration and coordination, but efforts to quantitatively demonstrate to what extent these improvements had translated into increased overall predictability of the Canadian government's permitting process were limited. According to officials from Natural Resources Canada, Canada's 2015 Economic Action Plan proposed providing C$135 million (U.S. $105 million) over 5 years, (starting in 2015-16) to continue to improve the efficiency and effectiveness of project approvals through the MPMO Initiative. Figure 7 shows key information about Canada's MPMO.

Figure 7: Canada's Major Projects Management Office



- The Major Projects Management Office provides guidance to project proponents and other stakeholders.
- It coordinates project agreements and timelines between federal departments and agencies.
- It tracks and monitors the progression of major resource projects through the federal regulatory review process.

Source: GAO summary of information on Canada's Major Projects Management Office. | GAO-16-699

Federal Approach to Addressing Critical Materials Supply Has Strengths but Is Not Consistent with Selected Collaboration Key Practices and Has Other Limitations

The federal government's approach to addressing critical materials supply issues has areas of strength, according to experts we surveyed, but is not consistent with selected key practices for enhancing and sustaining interagency collaboration and has other limitations. For example, federal government efforts to assess risks and conduct critical materials research have been identified by experts as strengths. However, the federal government's approach to addressing critical materials supply issues has not been consistent with selected key practices for interagency collaboration, such as ensuring that agencies' roles and responsibilities are clearly defined. In addition, the federal critical materials approach faces other limitations, including data limitations and a focus on only a subset of critical materials, a limited focus on domestic production of critical materials, and limited engagement with industry.

Surveyed Experts Identified Areas of Strength in the Federal Approach to Addressing Critical Materials Supply Issues

Experts that we surveyed identified areas of strength in the federal government's approach to addressing critical materials supply issues. The most commonly cited strengths were in federal efforts to identify and assess risks in certain industrial sectors and to conduct research related to critical materials. Among the strengths cited by experts in identifying and assessing risks was USGS's collection of data to support assessing critical materials supply risks. In particular, experts responding to the first round of our survey identified efforts by USGS to compile and provide data on mineral deposits and supply and demand for minerals as strengths.[46] One expert lauded USGS data and knowledge about the distribution of critical materials throughout the United States and the rest of the world. Another strength cited by an expert in the area of identifying and assessing risks included DLA-Strategic Materials' critical materials assessments. In the area of conducting research related to critical materials, experts cited DOE's CMI as a strength in the federal approach to developing methods that address the supply of critical materials, primarily rare earth materials. For example, one expert stated that the formation of CMI was a very positive step to address specific material shortages (rare earth materials, especially) from a scientific perspective, and to develop methods for using less material in specific applications, develop substitutes, and improve recycling of such materials. We found that the research funded by DOE's CMI has largely focused on projects related to rare earth materials. Specifically, according to DOE officials, 30 out of 34 of CMI's funded projects as of April 2016 have been related to rare earth materials.

In addition, experts in the second-round survey rated as adequate certain available data collected by the federal government in its effort to identify and assess risks with regard to the supply of critical materials. For example, when asked in the second-round survey to rate the adequacy of different types of critical materials data available, a majority of experts who responded described available data on (1) actual U.S. domestic production of materials and (2) resource potential and inventory for sources or deposits of materials located within the United States as somewhat or very adequate, as shown in table 1.

[46]In the first-round survey, experts responded to the following question: "What are the primary strengths of the U.S. federal government's policies and activities related to critical materials?" We did not ask about the strengths of specific government policies or activities. We highlight here examples of strengths cited by experts.

Table 1: Survey Results on Level of Adequacy or Inadequacy of Available Data to Assess Risks Associated with the Supply of Critical Materials

	Responses				
Categories of available data	**Very/somewhat adequate**	**Very/somewhat inadequate**	**Neither adequate nor inadequate**	**No opinion**	**Total**
Data on actual U.S. domestic production of materials	23	6	4	2	**35**[a]
Data on resource potential and inventory for sources or deposits of materials located within the United States	19	10	5	1	**35**[a]
Data on imports and exports of materials	17	12	5	1	**35**[a]
Data on the price of materials	17	10	7	1	**35**[a]
Data on the properties and substitutability of materials	15	8	9	3	**35**[a]
Data on the material composition of advanced technologies procured by the U.S. government, such as those required for national defense	14	12	4	5	**35**[a]

Source: Experts' responses to GAO survey. | GAO-16-699

Note: In response to the question "how adequate or inadequate are the data available in the categories listed below for the purposes of identifying and assessing risks associated with the supply of critical materials," experts were asked to rate the item on a five-point scale of very adequate, somewhat adequate, neither adequate nor inadequate, somewhat inadequate, very inadequate, or no opinion. For reporting purposes, we combined responses from the two adequate response options and from the two inadequate response options.

[a]Of the 46 experts we surveyed, 36 provided responses to the second-round survey. However, 1 expert did not respond to this question.

The Federal Approach to Addressing Critical Materials Supply Issues Is Not Consistent with Selected Key Practices for Interagency Collaboration

The federal government's approach to addressing critical materials supply issues is not consistent with selected key practices that we have previously identified that can help enhance and sustain interagency collaboration.[47] Collaboration can be broadly defined as any joint activity that is intended to produce more public value than could be produced when the organizations act alone. As described above, a number of federal agencies conduct activities related to critical materials supply across the primary areas of effort—assessing risk and supporting research—as well as a range of other activities. In our April 2015 guide to evaluating and managing fragmentation, overlap, and duplication, we

[47]GAO-06-15 and GAO-12-1022.

define fragmentation as those circumstances in which more than one federal agency, or organization within an agency, is involved in the same broad area of national need, and opportunities exist to improve service delivery.[48] This definition applies concerning federal agencies' critical materials activities, with more than one agency involved in the same broad area of national need. However, as shown by the agencies' critical materials activities described above, agencies' activities sometimes differ in meaningful ways or leverage the efforts of other agencies. In this context, we have reported that collaboration is an option that can reduce or better manage fragmentation of federal programs.[49]

As an interagency working group and according to its charter, the Subcommittee is to facilitate a strong, coordinated effort across its member agencies on critical minerals activities. However, we identified aspects of the Subcommittee's efforts, which represent the federal approach, that are not consistent with key practices for enhancing and sustaining interagency collaboration. These practices include agreeing on roles and responsibilities; establishing mutually reinforcing or joint strategies; and developing mechanisms to monitor, evaluate, and report on results.

Some Agencies Have a Subcommittee Role, but Other Agencies' Participation Has Been Limited and Roles and Responsibilities Have Not Been Clearly Defined

One practice we identified that can help enhance and sustain interagency collaboration is agreeing on roles and responsibilities, including leadership.[50] We reported that collaborating agencies should work together to define and agree on their respective roles and responsibilities, including how the collaborative effort will be led. In doing so, agencies can clarify who will do what, organize their joint and individual efforts, and facilitate decision making. Consistent with this practice, OSTP, DOE, and USGS have taken key roles as co-chairs of the Subcommittee.

However, there are a number of Subcommittee member agencies, such as Education, Labor, EPA, DHS, and USDA, that are designated as members in the Subcommittee charter but do not have clear roles within

[48]GAO, *Fragmentation, Overlap, and Duplication: An Evaluation and Management Guide*, GAO-15-49SP (Washington, D.C.: Apr. 14, 2015).

[49]GAO-15-49SP.

[50]GAO-06-15.

the Subcommittee's efforts and have had limited or no involvement in the Subcommittee's work on critical materials. For example:

- EPA officials stated that EPA is in a unique position to lead in certain government-wide efforts, such as electronic waste recycling, that could be important for facilitating the recycling and reuse of critical materials. However, one EPA official stated that EPA viewed its role on the Subcommittee as limited. Specifically, EPA has had some involvement as a member of the Subcommittee but has not been coordinating with the Subcommittee on federal efforts to facilitate the recycling and reuse of critical materials. EPA officials stated that the Subcommittee's activities were being driven primarily by other agencies, and EPA officials did not view the Subcommittee's activities as being focused on sustainable materials management—an area where EPA has expertise.
- Education and Labor lead federal efforts on education and workforce issues. A 2013 National Academies of Sciences, Engineering, and Medicine report on workforce trends in the U.S. energy and mining industries highlighted the role that Education and Labor could play in helping to address education and workforce issues related to those industries, which include industries related to the supply of critical materials.[51] Among the report's recommendations was for Education to collaborate with Labor, state departments of education, and national industry organizations to convene workshops with industry, government, and educational leaders.[52] However, although Education and Labor are designated as members in the Subcommittee charter, neither has shown that it ever participated in Subcommittee meetings. Officials from Labor stated that they were unaware of the Subcommittee and their agency's designation as a member on the Subcommittee until we contacted them during the course of this review. Officials from Education stated that they were unable

[51]National Research Council, *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action* (Washington, D.C.: 2013).

[52]According to the National Research Council report, the workshops would allow government and industry officials to create and support new approaches that provide multiple pathways in higher education related to energy and mining through, for example, partnerships between community colleges and 4-year universities and colleges.

to identify anyone who participated on the Subcommittee and that there were no records of anyone from Education having participated.

- USDA's Forest Service reviews and approves mine plans for operations that have included the mining of critical materials on the lands it manages. Although USDA is designated a member of the Subcommittee in its charter, according to agency officials, USDA did not have representation on the Subcommittee until August 2015 when a mining operator applying for a permit informed Forest Service officials about the Subcommittee. Forest Service officials told us that because they now know about their role on the Subcommittee, they plan to attend meetings regularly and be more involved in activities.
- DHS analyzes U.S. dependence on foreign infrastructure, including foreign sources of critical materials. The agency is designated as a Subcommittee member in the charter; however, DHS officials stated that, until we contacted them during the course of our review, no one had been tasked to represent the agency on the Subcommittee. A DHS official told us that he is now on OSTP's list of agency contacts for the Subcommittee. DHS analyses of foreign infrastructure could help to inform the analysis that the Subcommittee has developed for the early warning screening system, as well as DOD's analyses for its stockpiling assessments.

Some experts we surveyed also noted the lack of clarity in agencies' roles and responsibilities with regard to federal coordination efforts in addressing the supply of critical materials. Sixteen out of 36 experts responding to our survey indicated that the roles and responsibilities of government agencies with respect to critical materials were not very clearly defined or not defined at all.[53] For example, one expert stated that too many agencies have their own agendas and therefore the federal effort is not coordinated. Relatedly, another expert noted that Commerce

[53]In response to the question "how clearly defined, if at all, are the roles and responsibilities of government agencies with respect to critical materials," experts were asked to rate the item on a scale of very clearly defined, somewhat clearly defined, not very clearly defined, not defined at all, or no opinion. Experts who selected somewhat clearly defined or not very clearly defined were then asked to describe any roles that have not been well defined, such as those for a particular agency or activity.

does not have a clearly defined role to support critical materials important to the economy.

Our work has shown that although collaborative mechanisms differ in complexity and scope, they all benefit from certain key features, including the clarity of roles and responsibilities and ensuring that the relevant participants are included in the collaborative effort.[54] Specifically, key practices call for participating agencies to consider clarifying their roles and responsibilities and whether all relevant participants have been included. We have reported that clarity about roles and responsibilities can be codified through laws, policies, memorandums of understanding, or other requirements. By agreeing on and clearly defining roles and responsibilities of their members, collaborating agencies clarify which agency will do what, organize their joint and individual efforts, and facilitate decision making. Furthermore, experts we contacted for our 2012 report on key considerations for implementing interagency collaborative mechanisms said, among other things, that it is helpful when the participants in a collaborative mechanism have full knowledge of the relevant resources in their agency and the ability to commit these resources and make decisions on behalf of the agency.[55]

We noted earlier that the EU has created a mechanism to bring together relevant stakeholders in the area of critical materials to align priorities, leverage investments, and form future partnerships. According to OSTP officials, the Subcommittee's efforts are generally based on the level of involvement and resources of member agencies, with certain agencies taking the lead for certain activities. However, OSTP, as part of the Subcommittee's leadership, did not point to efforts made to engage member agencies in more active participation in the Subcommittee. By taking steps to actively engage all member agencies in its efforts and clearly define roles and responsibilities, the Subcommittee will have more reasonable assurance that it can effectively marshal the potential contributions of all member agencies to take full advantage of their expertise and resources to help identify and mitigate critical materials

[54]GAO-12-1022. Ensuring that all relevant participants are included in the collaborative effort was not distinctly identified as a key practice in our 2005 report, but was included in our 2012 report.

[55]GAO-12-1022.

supply risks. Moreover, the 1980 Act outlines a range of policies to promote an adequate and stable supply of materials, including assessing the availability of technically trained personnel, as well as supporting research related to recovery and recycling of materials, among others.[56] In addition to enhancing interagency collaboration on critical materials activities, actively engaging all member agencies may also present an opportunity for the Subcommittee to more fully incorporate the policies of the 1980 Act into the federal approach for addressing critical materials supply issues.

Federal Efforts Are Not Guided by Joint Strategies to Achieve a Common Outcome

Another key practice we identified that can enhance and sustain interagency collaboration is establishing mutually reinforcing or joint strategies designed to help align activities, core processes, and resources to achieve a common outcome.[57] However, federal critical materials efforts are not guided by joint strategies to achieve a common outcome. The Subcommittee's charter outlines general areas of effort for its work but does not specify the outcome or outcomes that the Subcommittee plans to achieve. The Subcommittee's member agencies have not worked together to develop joint strategies to guide their activities. OSTP officials indicated that member agencies are responsible for determining which activities to undertake based on the agencies' resources and mission. The Subcommittee does not direct member agency activities, and there has been no discussion within the Subcommittee of creating a joint strategy. Experts also identified issues with the extent to which the federal approach to addressing critical materials supply issues supports achieving desired outcomes in response to our survey. For example, 28 out of 36 experts responding to our survey indicated that the federal government's objectives with respect to critical materials were not clearly

[56]Specifically, the 1980 Act calls for assessing the need for and making recommendations concerning the availability and adequacy of the supply of technically trained personnel necessary for materials research, development, extraction, harvest, and industrial practice, paying particular regard to the problem of attracting and maintaining high-quality materials professionals in the federal service, and the support of research and development to provide for improved methods of recovery and recycling of materials that encourage the conservation of materials, energy, and the environment.

[57]GAO-06-15.

defined or not defined at all,[58] and 20 out of 36 indicated that the extent to which federal agencies' activities are mutually reinforcing with regard to critical materials was small or nonexistent.[59]

We have previously reported that to achieve a common outcome, collaborating agencies need to establish strategies that work in concert with those of their partners or are joint in nature.[60] Developing joint strategies can help align partner agencies' activities, core processes, and resources to accomplish a common outcome. Developing joint strategies to articulate common outcomes and identify member agencies' efforts could help the Subcommittee better coordinate agencies' critical materials activities to ensure that they are mutually reinforcing.

The Subcommittee Does Not Have a Mechanism to Monitor, Evaluate, and Report Its Efforts

An additional key practice we identified that can enhance and sustain interagency collaboration is developing mechanisms to monitor, evaluate, and report results.[61] Federal agencies engaged in collaborative efforts need to create the means to monitor and evaluate their efforts to enable them to identify areas for improvement. However, the Subcommittee does not have a mechanism to monitor and evaluate progress across all areas of its activities. OSTP officials did not think that monitoring the progress of activities was the Subcommittee's responsibility because individual activities are funded by member agencies, and therefore those agencies would be responsible for tracking progress. However, without a mechanism to monitor and evaluate its efforts, the Subcommittee may be missing an opportunity to fulfill a policy of the 1980 Act, which calls for establishing a mechanism to evaluate federal materials programs.

Also, key practices call for reporting on the activities of agencies engaged in collaborative efforts to help key decision makers within the agencies,

[58]In response to the question "how clearly defined, if at all, are the federal government's objectives with respect to critical materials," experts were asked to rate the item on a scale of very clearly defined, somewhat clearly defined, not very clearly defined, not defined at all, or no opinion.

[59]In response to the question "to what extent are the activities of federal agencies mutually reinforcing with respect to critical materials," experts were asked to rate the item on a scale of to a large extent, to a moderate extent, to a small extent, not at all, or no opinion.

[60]GAO-06-15.

[61]GAO-06-15.

as well as clients and stakeholders, obtain feedback for improving both policy and operational effectiveness. OSTP officials stated that they provide reports as necessary on specific Subcommittee activities, in line with the reporting practices for other NSTC subcommittees. For example, as noted earlier, in March 2016, the Subcommittee published a report on its progress in developing a screening methodology for critical minerals and the results of the initial application of this methodology. However, since it was established in 2010, the Subcommittee has not reported periodically on the progress of all of its efforts to address critical materials supply issues. According to OSTP officials, the Subcommittee leaves regular reporting on the progress of activities to the member agencies as part of their standard agency oversight measures. However, there is no member agency that is responsible for reporting on all of the Subcommittee's efforts. Periodic reporting on the progress of the Subcommittee's activities could help key decisionmakers within the member agencies and Congress, as well as other stakeholders, to obtain feedback for improving both policy and operational effectiveness.

Federal Approach to Addressing Critical Materials Supply Issues Faces Other Limitations

We identified other limitations in the federal approach to addressing critical materials supply issues through our expert survey, review of the Subcommittee's criticality assessment, and analysis of other information we collected. These include limitations in the federal government's engagement with industry to identify U.S. critical material needs, with data to identify and assess risks and the Subcommittee's focus on only a subset of critical materials, and in the Subcommittee's focus on domestic production of critical materials.

Federal Engagement with Industry to Identify Materials Needs across the U.S. Economy Has Been Limited

The federal government's engagement with industry on an economy-wide basis to identify critical materials supply issues has been limited, according to our analysis and responses from the experts we surveyed. Although DOE and DOD have engaged with industry stakeholders in the clean energy and defense sectors through their efforts to address critical materials supply issues, we found that there has been limited federal government engagement with industry stakeholders outside of energy and defense. For example, officials that we interviewed from the semiconductor industry told us that they have concerns about the availability of certain gases that are critical to the semiconductor manufacturing process. However, company officials stated that they had not spoken with anyone within the federal government about their concerns; one trade association official stated that the organization did not know where in the federal government it should go to raise these concerns and that it was not aware of mechanisms to communicate

information about supply disruptions to the government. Additionally, in response to our survey, a majority of experts, 25 out of 36, indicated that the level of attention that the federal government has paid to the criticality of materials important to industrial sectors outside of energy and defense was very or somewhat inadequate.[62] In comparison, slightly more than half of the experts we surveyed, 19 out of 36, indicated that the level of attention paid to materials important to sectors related to energy and defense was very or somewhat adequate.[63]

Commerce is responsible for soliciting information from a range of industry sectors to help identify and assess cases of materials needs. The 1980 Act requires Commerce, in consultation with other agencies, to continually identify and assess cases of materials needs, as necessary, to ensure an adequate and stable supply of materials to meet national security, economic well-being, and industrial production needs.[64] In the early 1980s after the legislation was enacted, Commerce conducted two such assessments on critical materials related to the aerospace and steel industries.[65] Both assessments were conducted by Commerce's Minerals and Materials Task Force, which was chaired by the Director of ITA's Office of Strategic Resources. However, Commerce officials could not identify any recent assessments on critical materials by the department. Commerce's Office of Technology Evaluation within the Bureau of Industry and Security conducts industrial base surveys and assessments, but according to Commerce, those assessments are focused exclusively

[62]In response to the question "overall, how adequate or inadequate is the level of attention that the U.S. federal government has paid to the following areas in its approach to critical materials," experts were asked to rate the item on a scale of very adequate, somewhat adequate, neither adequate nor inadequate, somewhat inadequate, very inadequate, or no opinion.

[63]In response to the question "overall, how adequate or inadequate is the level of attention that the U.S. federal government has paid to the following areas in its approach to critical materials," experts were asked to rate the item on a scale of very adequate, somewhat adequate, neither adequate nor inadequate, somewhat inadequate, very inadequate, or no opinion.

[64]30 U.S.C. § 1604(c)(3) (2016).

[65]Department of Commerce, *Critical Materials Requirements of the U.S. Aerospace Industry* (Washington, D.C.: 1981), and *Critical Materials Requirements of the U.S. Steel Industry* (Washington, D.C.: 1983).

on the U.S. defense industrial base. Within Commerce, nondefense assessment functions reside in ITA.

ITA held two industry roundtables related to critical materials, one in 2009 focused on rare earth materials and another in 2012 that was intended to help inform the Subcommittee's assessment of critical minerals. According to ITA officials, roundtables are convened periodically, often when there is something new or important affecting industry, such as the concerns about the decreased global supply of rare earth materials. According to the officials, ITA's role on the Subcommittee is to provide support by sharing and exchanging information from an industry and trade perspective. The officials indicated that ITA has no specific plans to conduct additional roundtables to identify industry concerns related to critical materials supply. ITA officials also stated that it was not within the purview of ITA's industry-specific offices—Office of Energy and Environment Industries, Office of Health and Information Technology, and Office of Transportation Machinery—to meet with industry to engage on issues related to critical materials supply. ITA officials stated that they were not aware of Commerce's responsibilities under the 1980 Act prior to our review.

Proactive engagement with a range of industry stakeholders to identify critical materials needs was a feature we identified in other countries' or regions' approaches to address critical materials supply issues. For example, the Japanese government's approach features close collaboration between government and industry through engagement with industrial stakeholders to develop materials flow analyses that can identify critical materials and pinpoint bottlenecks in supply chains. Because Commerce is not engaging with industry stakeholders across a range of industrial sectors to identify materials of concern, it may not have the comprehensive, current information it needs to fulfill its responsibilities under the 1980 Act to continually identify and assess cases of materials needs.

Experts Surveyed Found Some Data to Be Very or Somewhat Inadequate, and the Subcommittee Focuses on a Subset of Critical Materials

The federal approach to addressing critical materials supply issues is limited by the inadequacy of certain data and a focus on a subset of critical materials. While experts we surveyed were generally positive about data on domestic production, resource potential and inventory, and imports and exports associated with the supply of critical materials, as described earlier, a majority of them found available data to identify and assess risks associated with the supply of critical materials to be very or somewhat inadequate. As shown in table 2, a majority of experts who responded to the survey thought that the availability of data was

inadequate in a number of areas, including data to identify and assess risks on (1) actual foreign production; (2) the resource potential of critical materials in other parts of the world, including in and below the oceans; and (3) the quantity of material recycled.

Table 2: Survey Results on Level of Adequacy or Inadequacy of Available Data to Identify and Assess Risks Associated with the Supply of Critical Materials

	Responses				
Categories of available data	**Very/somewhat adequate**	**Very/somewhat inadequate**	**Neither adequate nor inadequate**	**No opinion**	**Total**
Data on actual foreign production	8	23	3	1	**35**[a]
Data on resource potential for other parts of the world, including in and below the oceans	3	26	4	2	**35**[a]
Data on the quantity of material recycled	6	22	6	1	**35**[a]
Data on the quantity of materials consumed for production of advanced technologies in the U.S. economy	11	15	7	2	**35**[a]
Data on the quantity of materials consumed for production of advanced technologies globally (outside the United States)	6	20	7	2	**35**[a]
Data on the location and amount of materials processed abroad	6	21	6	1	**34**[a]
Data on the ownership and sources of financing of companies that produce or process materials for U.S. industry	10	15	4	6	**35**[a]

Source: Experts' responses to GAO survey. | GAO-16-699

Note: In response to the question "how adequate or inadequate are the data available in the categories listed below for the purposes of identifying and assessing risks associated with the supply of critical materials," experts were asked to rate the item on a five-point scale of very adequate, somewhat adequate, neither adequate nor inadequate, somewhat inadequate, very inadequate, or no opinion. For reporting purposes, we combined responses from the two adequate response options and from the two inadequate response options.

[a]Of the 46 experts we surveyed, 36 provided responses to the second-round survey. However, 1 expert did not respond to this question and 1 expert did not respond to the specific question on available data on the location and amount of materials processed abroad.

In addition, the Subcommittee's March 2016 criticality assessment reporting on the development and initial application of a screening methodology represents an important step toward developing an early warning system. However, the report focuses on a subset of potential critical minerals, which it defined as nonfuel resources—elements or compounds—that are obtained by mining or refined from mined products, and in some cases includes such substances at various stages of processing. According to the Subcommittee's report, the subset of

minerals assessed in this initial screening was determined by the availability of suitable and consistent data. The report noted that, in addition to limitations of scope, a significant weakness common among all known criticality assessments is that they are not updated regularly, likely because of the complexity of the models employed, lack of necessary data, or lack of resources needed to perform such updates. Relatedly, the Subcommittee's 2010 charter established that one of the functions of the Subcommittee would be to develop and periodically update methods for assessing the criteria for material designations as critical or strategic in the short, medium, and long terms, including an early warning mechanism for emerging critical or strategic materials. However, the Subcommittee's 2016 charter narrowed this function to implement and, as necessary, update the methodology developed cooperatively by its member agencies for dynamically assessing mineral criticality and for signaling emerging critical or strategic minerals—notably replacing the word material with mineral.

The Subcommittee's focus on minerals excludes other materials that are important to industry and federal scientific research, such as rare gases like neon and argon.[66] For instance, we learned from industry officials we interviewed that beginning in 2014 during the conflict between the Ukrainian government and Russian-backed separatist groups, there was a decrease in the global supply of neon gas that led to a 20-fold price increase. Neon is generally produced as a by-product of steelmaking, and most of the global supply of neon comes from Ukraine and Russia.[67] Neon is used for many industrial and research applications, including in the medical field and in the semiconductor industry to design computer chips.[68] For instance, an NIH official stated that the agency found out

[66]Industrial gases include the rare, or inert, gases on the periodic table, such as helium, neon, and argon, as well as nonrare gases such as nitrogen and oxygen. Although neon is among the common elements in the universe—with hydrogen, helium, oxygen, and carbon being more abundant—the inert gas is scarce on Earth. In air, its concentration is only approximately 18 parts per million by volume.

[67]Approximately 70 percent of the world's neon comes from Ukraine and Russia, and most U.S. industrial gas imports come from Ukraine.

[68]The semiconductor industry consumes more than 70 percent of the world's production of neon in laser light sources used to design computer chips. The rare gas is also used in lasers for medical research and applications and as a preferred refrigerant for certain applications.

about the decreased global supply of neon through one of its grantees that needed the gas for medical research. According to the NIH official, the decreased supply of neon gas has resulted in researchers rationing the gas, which restricts research activities. The official stated that in one case the agency provided supplemental funds to assist a researcher in conducting experiments using alternative laser systems that did not depend on neon gas, but the experiments were unsuccessful using those lasers. According to the NIH official, federal intervention to ensure the availability of neon and other rare gases would improve the agency's ability to advance its mission.

The Subcommittee's criticality assessment report notes that the development of the screening methodology and the regular publication of its results address aspects of the 1980 Act. As noted above, the 1980 Act calls for the creation of early warning systems for materials supply problems, and defines "materials" as substances, including but not limited to minerals, needed to supply the industrial, military, and essential civilian needs of the United States. The Subcommittee's report indicated that additional minerals could be included in the early warning screening in the future as additional data become available. However, the Subcommittee has not developed a plan or strategy to prioritize additional materials needed by industry and federal research and to determine how to obtain data that would allow them to be included in the early warning screening in the future.

One potential mechanism for obtaining data on additional materials is the North American Industry Classification System, which is the standard used by federal statistical agencies—several of which are part of Subcommittee member agencies (e.g., Labor's Bureau of Labor Statistics and DOE's Energy Information Administration)—in classifying business establishments to collect, analyze, and publish statistical data related to the North American economy. The system is reviewed through an international process every 5 years and uses a production-oriented conceptual framework to group establishments into industries based on the activity in which they are primarily engaged. Establishments using similar raw material inputs, similar capital equipment, and similar labor are classified in the same industry, so that establishments that do similar

things in similar ways are classified together.[69] The current 2012 industry classifications in use under this system were issued in 2011. The U.S Economic Classification Policy Committee is reviewing comments on its recommendations for the 2017 revisions to the system, after which it will begin the process of soliciting proposed revisions for implementation in 2022.[70] During the revision process, the Economic Classification Policy Committee solicits and evaluates requests for revisions to the North American Industry Classification System. A Labor official said that if there is a need to classify segments of industries at a more granular level, it would be important to communicate these needs for the next revision cycle. For example, there is one North American Industry Classification System code that covers all industrial gases.[71] If the Subcommittee found that there was the need for additional information on a specific industrial gas, such as neon, it could use the upcoming revision process to request a change to incorporate additional granularity into the system to differentiate between different industrial gases. This would be similar to the changes the Subcommittee worked with the United States International Trade Commission to incorporate in the Harmonized Tariff Schedule to provide more visibility into the imports of specific rare earth materials and permanent magnets.

Since the publication of the Subcommittee's criticality report, the Subcommittee narrowed its charter to focus on minerals. In narrowing the charter, the Subcommittee is missing the opportunity to fulfill in its early warning screening methodology one of the policies of the 1980 Act, which applies to all critical materials. By taking the steps necessary to broaden future applications of the early warning screening methodology to include potentially critical materials beyond minerals, such as a plan or strategy for prioritizing the materials, the Subcommittee could better work with

[69]Additionally, the North American Product Classification System is a complementary system to the North American Industry Classification System. The North American Product Classification System classifies the outputs, products, or transactions of establishments within a demand-based conceptual framework.

[70]The U.S. Economic Classification Policy Committee is an interagency committee under OMB charged with the maintenance and review of the North American Industry Classification System. In doing so, the committee coordinates with partners in Canada and Mexico.

[71]There is also a product code under the North American Product Classification System that covers industrial gases.

member agencies to address existing data limitations and broaden the scope of the early warning system to better achieve the policy outlined in the 1980 Act.

Federal Approach to Addressing Critical Materials Supply Issues Has a Limited Focus on Domestic Production

Experts we surveyed noted the importance of domestic production in addressing the supply of critical materials but also indicated that the federal government's approach to date has included a limited focus on domestic production. The 1980 Act calls for the coordination of federal agencies to facilitate the availability and development of domestic resources to meet critical materials needs, and the assessment of federal policies that affect all stages of the materials cycle, including mining. A majority of experts who responded to the survey, 24 out of 36, indicated that the federal government should play a major role in encouraging the domestic production of critical materials, and 19 out of 36 indicated that federal efforts to encourage domestic production of critical materials to address supply issues are somewhat or very inadequate.[72] As shown in table 3, experts we surveyed identified several factors with the potential to limit domestic production of critical materials.

Table 3: Survey Results on Level of Significance of Factors with Potential to Limit Domestic Production of Critical Materials

	Responses					
Factors with potential to limit domestic production[a]	**Very significant**	**Significant**	**Somewhat significant**	**Not significant**	**No opinion**	**Total**
Lack of federal government mechanisms to help finance domestic production of critical materials, such as tax incentives or other mechanisms	13	10	4	4	5	**36**
Level of public awareness and support for domestic production of raw materials for the U.S. economy	14	9	4	7	2	**36**
Reclamation closure requirements, lawsuits, and liabilities (e.g., for remediation) associated with mines	16	4	8	5	3	**36**

[72]In response to the question "overall, how adequate or inadequate are federal efforts to encourage domestic production of critical materials to address critical materials supply risk," experts were asked to rate the item on a five-point scale of very adequate, somewhat adequate, neither adequate nor inadequate, somewhat inadequate, very inadequate, or no opinion.

Factors with potential to limit domestic production[a]	Responses					Total
	Very significant	Significant	Somewhat significant	Not significant	No opinion	
Length of permitting process for new mines	23	4	6	0	3	**36**
Environmental, health, and safety regulations and standards pertaining to critical materials	14	5	9	6	2	**36**

Source: Experts' responses to GAO survey. | GAO-16-699

Note: Experts were asked the following question: "How significant, if at all, are the following factors in terms of their potential to limit domestic production of critical materials for the U.S. economy?"

[a]These factors were identified through our analysis of the results of the first round of our expert survey in which we asked open-ended questions about the primary strengths and weaknesses of the U.S. federal government's policies and activities related to critical materials and challenges and options for improving these efforts. In the second round of our survey, we asked experts to rate the significance of these factors. For additional information on our survey methodology, see app. I.

As described above, one aspect of domestic production of critical materials is the review and approval by federal agencies of mining projects on federal land. As shown in table 3, most experts we surveyed indicated that the length of the permitting process for new mines has the potential to limit the domestic production of critical materials. In January 2016, we reported on the permitting process involving BLM and the Forest Service and found, among other things, that agency officials felt that there was limited or ineffective interagency coordination and collaboration during the mine plan review process.[73] We reported that officials in nine BLM and two Forest Service locations said that coordination and collaboration had been limited in both quantity and quality and had resulted in adding from 2 months to 3 years to the review process. As part of the review process, BLM and the Forest Service need to coordinate and collaborate with other federal agencies, state agencies, and Native American tribes on issues such as assessing impacts to water quality, wildlife, and cultural resources.[74] However, BLM and Forest

[73]GAO, *Hardrock Mining: BLM and Forest Service Have Taken Some Actions to Expedite the Mine Plan Review Process but Could Do More*, GAO-16-165 (Washington, D.C.: Jan. 21, 2016).

[74]Experts we surveyed stated that the federal government's coordination with state governments as external stakeholders on identifying and assessing risks across the spectrum of critical materials was inadequate. Thirteen out of 18 experts who expressed an opinion on this question said that federal coordination with states was somewhat or very inadequate.

Service officials said it can be difficult to do. For example, Forest Service officials said that a federal agency delayed the review process for one mine plan because the agency did not provide the necessary data in a timely fashion. As a result, Forest Service officials had to redo some analyses needed for the mine plan's environmental impact statement, which added time to the review process. To help address this key challenge, some officials said that they have developed memorandums of agreement with state agencies, are holding regular meetings with these state agencies, and the mine operators, and are communicating and consulting with tribes.

As noted above, other countries' or regions' approaches to addressing critical materials supply issues have incorporated taking steps to facilitate domestic production of materials. For example, Canada's MPMO Initiative was established to improve the accountability, transparency, timeliness, and predictability of Canada's federal regulatory review process for major resource projects, and internal and external stakeholders believe that federal project review timelines have improved because of better coordination. The Canadian government has also taken steps to provide tax incentives for domestic production. Similarly, as described above, fostering communication with stakeholders related to new mining projects has been a facet of the EU approach to facilitating domestic production of critical materials. Although its charter calls for the Subcommittee to review and analyze global and domestic policies that affect the supply of critical and strategic minerals, the Subcommittee has addressed these issues only to a limited degree. As noted above, the Subcommittee has done some work to look at trade issues to critical materials through its work with USTR and other member agencies to address China's export restrictions through dispute settlement at the WTO. However, the Subcommittee has not focused on increasing the supply of critical materials through facilitating domestic production. Until recently, the Forest Service was not an active participant on the Subcommittee, and according to BLM officials we interviewed, BLM has not participated on the Subcommittee. There are a number of global and domestic policies related to the supply of critical materials that the Subcommittee could review and analyze, including examining the approaches taken by other countries or regions to facilitate domestic production by, for example, improving coordination and streamlining the mine-permitting process. By examining the approaches taken by other countries or regions to facilitate domestic production of critical materials, the Subcommittee could determine if there are any lessons learned that could be applied to the United States.

Conclusions

The availability of certain materials is essential for national security, economic well-being, and industrial production. Recognizing this need, Congress passed the 1980 Act to promote an adequate and stable supply of needed materials. Although this legislation has been in place for over 30 years, a number of the key federal activities we examined that are focused on addressing critical materials supply risk did not begin until after 2010, when China tightened its export restrictions on rare earth materials.

U.S. government agencies are now carrying out some of the policies outlined in the 1980 Act, and experts have identified strengths in agencies' efforts to assess critical materials supply risks and mitigate those risks through research activities. Although the Subcommittee is to facilitate a strong, coordinated effort across its member agencies on critical minerals activities, its efforts to coordinate agencies' activities are not consistent with selected key practices for enhancing and sustaining interagency collaboration. The Subcommittee has not taken steps to actively engage all member agencies in its efforts and has not clearly defined the roles and responsibilities of member agencies. By ensuring that all relevant member agencies are engaged in its efforts and have agreed on and clearly defined roles and responsibilities, the Subcommittee will have more reasonable assurance that it can effectively marshal the potential contributions of all member agencies to take full advantage of their expertise and resources in addressing critical materials supply issues. The Subcommittee also has not developed joint strategies to articulate common outcomes and identify contributing agencies' efforts, or developed a mechanism to monitor, evaluate, and periodically report on the progress of these efforts. Developing joint strategies to articulate common outcomes and identify member agencies' efforts could help the Subcommittee better coordinate agencies' critical materials activities to ensure that they are mutually reinforcing. In addition, developing a mechanism to monitor, evaluate, and periodically report on the progress of member agencies' efforts could help the Subcommittee fulfill a policy of the 1980 Act, which calls for the establishment of a mechanism for the evaluation of federal materials programs.

The U.S. government is also missing other key opportunities to address critical materials supply risks because of its limited engagement with industry to continually identify and assess materials needs, a focus on a subset of critical materials, and a limited focus on developing domestic production capabilities. The Subcommittee has taken an important step toward developing an early warning system for critical minerals as called for by its charter, but it excludes nonmineral materials that may be

important to industry and federal research. Currently, the Subcommittee does not have a documented plan or strategy to prioritize potentially critical materials beyond minerals and determine how to obtain data on such materials that would allow them to be included in the early warning screening in the future. By taking the steps necessary to broaden its future applications of the early warning screening methodology to include potentially critical materials beyond minerals, including a plan or strategy for prioritizing such materials, the Subcommittee could better work with member agencies to address existing data limitations and broaden the scope of the early warning system to better achieve the policy outlined in the 1980 Act.

The Subcommittee is also not taking steps to identify opportunities to facilitate domestic production as a way to mitigate critical materials supply risks. As provided for by the Subcommittee's charter, examining how other countries or regions, such as Canada and the EU, are improving coordination and streamlining the mine-permitting process could help the Subcommittee determine if there are any lessons learned that could be applied to the United States. Finally, Commerce has not engaged with industry stakeholders to solicit information across a range of industrial sectors. While Commerce has coordinated with industry at certain times or on specific issues, these coordination efforts have been ad hoc and have generally focused on the defense industrial base. As a result, Commerce may not have the comprehensive, current information it needs to fulfill its responsibilities under the 1980 Act to continually identify and assess cases of materials needs.

Recommendations for Executive Action

To enhance the ability of the Executive Office of the President to coordinate federal agencies to carry out the national materials policy outlined in the 1980 Act, we recommend that the Director of the Office of Science and Technology Policy, working with the National Science and Technology Council's Subcommittee on Critical and Strategic Mineral Supply Chains and agency leadership, as appropriate, take the following five actions:

- To strengthen the federal approach to addressing critical materials supply issues through enhanced interagency collaboration, the Subcommittee should
- agree on and clearly define the roles and responsibilities of member agencies and take steps to actively engage all relevant federal agencies in the Subcommittee's efforts;

- develop joint strategies that articulate common outcomes and identify contributing agencies' efforts; and
- develop a mechanism to monitor, evaluate, and periodically report on the progress of member agencies' efforts.
- To broaden future applications of the early warning screening methodology, the Subcommittee should take the steps necessary to include potentially critical materials beyond minerals, such as developing a plan or strategy for prioritizing additional materials for which actions are needed to address data limitations.
- To enhance the federal government's ability to facilitate domestic production of critical materials, the Subcommittee should examine approaches other countries or regions are taking to see if there are any lessons learned that can be applied to the United States.

To fulfill the role assigned to it under the 1980 Act, the Secretary of Commerce should engage with industry stakeholders and continually identify and assess critical materials needs across a broad range of industrial sectors.

Agency Comments, Third-Party Views, and Our Evaluation

We provided a draft of this report to USDA, Commerce, DOD, Education, DOE, HHS, DHS, Interior, Justice, Labor, State, Treasury, EPA, NASA, NSF, CEQ, NEC, NSC, OMB, OSTP, and USTR for review and comment. We received the following comments:

- OSTP provided written comments, which are reproduced in appendix III. Of the five recommendations directed to it, OSTP neither agreed nor disagreed with four of the recommendations, but expressed some concerns with three of the recommendations as described below, and concurred with the fifth recommendation.
- Commerce provided written comments, which are reproduced in appendix IV. Specifically, in its comments Commerce stated it agreed with the recommendations and that it will consult with other agencies in order to develop an action plan with details on implementation.
- USDA provided written comments, which are reproduced in appendix V. USDA stated that it generally agreed with the draft report, stating that it supported the Subcommittee and that it agreed that there are limitations, including limited engagement with industry and limited focus on domestic production. USDA did not comment on the recommendations.
- In an email from an audit analyst in its Office of the Chief Financial Officer, DOE provided general comments, which we discuss below.

- Commerce, DOD, DOE, Interior, NASA, and USTR provided technical comments, which we incorporated as appropriate.
- Officials from Education, HHS, DHS, Justice, Labor, State, Treasury, EPA, NSF, and NSC stated via email that they had no comments on the report.
- An NEC official stated that NEC had no comments on the report.
- CEQ and OMB did not provide comments.
- Additionally, we provided a draft of this report to Natural Resources Canada, the European Commission Directorate-General for Internal Market, Industry, Entrepreneurship and Small and Medium-sized Enterprises, METI, and Japan's Ministry of Education, Culture, Sports, Science and Technology for their views and comments on the completeness and accuracy of GAO's information on their programs and practices. Officials from the EU and Canada provided technical comments via email, which we incorporated as appropriate. Officials from Japan stated in emails that they had no comments on the report.

In its written comments, OSTP neither agreed nor disagreed with our first three recommendations that the Subcommittee should (1) agree on and clearly define the roles and responsibilities of member agencies and take steps to actively engage all relevant federal agencies in the Subcommittee's efforts; (2) develop joint strategies that articulate common outcomes and identify contributing agencies' efforts; and (3) develop a mechanism to monitor, evaluate, and periodically report on the progress of member agencies' efforts. In its comments, OSTP stated that the roles and responsibilities of member agencies are defined by their existing missions and that further specification of roles and responsibilities within the context of the Subcommittee is either redundant, if aligned with agency missions, or may raise confusion if not. However, as we state in the report, there are a number of Subcommittee member agencies that do not have clear roles within the Subcommittee's efforts and have had limited or no involvement in the Subcommittee's work on critical materials. By clearly defining roles and responsibilities within the context of the Subcommittee, member agencies could organize their joint and individual efforts, and facilitate decision making. Moreover, more actively engaging all member agencies by clearly defining roles and responsibilities and identifying contributing activities could help the Subcommittee more fully incorporate the range of policies of the 1980 Act into the federal approach for addressing critical materials supply issues. OSTP further stated that agencies have in place mechanisms to monitor, evaluate, and report on the progress of their efforts in support of their missions, and the Subcommittee reports directly to its parent committee

and in other ways (public documents) on its collective actions. However, as we state in the report, the Subcommittee has not reported periodically on the progress of all of its efforts to address critical materials supply issues, and there is no member agency that is responsible for reporting on all of the Subcommittee's efforts. We continue to believe that OSTP should fully implement our three recommendations to enhance interagency collaboration on critical materials supply issues.

OSTP neither agreed nor disagreed with our fourth recommendation that the Subcommittee should take the steps necessary to include potentially critical materials beyond minerals, such as developing a plan or strategy for prioritizing additional materials. In its comments, OSTP stated that plans to address additional materials are under discussion as the Subcommittee evaluates feedback on the published assessment methodology and that other approaches may be considered to add potentially critical materials that cannot be screened using the methodology because of data limitations or other factors. DOE, which co-chairs the Subcommittee along with OSTP and Interior, stated in its general comments that the report would more accurately present the issue of the federal focus on only a subset of materials by including a more comprehensive discussion of the data availability issues that limit the Subcommittee's early warning screening methodology. We acknowledge that existing data limitations present a challenge for the Subcommittee. As we state in the report, our recommendation that the Subcommittee take steps such as developing a plan or strategy for prioritizing additional materials to be included in the early warning screening methodology is intended to help the Subcommittee better work with member agencies to address existing data limitations. In its general comments, DOE also suggested that we clarify that the plan or strategy for prioritizing additional materials should focus on those that require augmented data collection activities. As we state in our report, addressing data limitations is a key factor in the Subcommittee's ability to apply its early warning screening methodology to additional materials. Therefore, we clarified in the recommendation the role of data limitations. Without taking steps to include potentially critical materials beyond minerals, such as developing a plan for prioritizing additional materials, the Subcommittee may miss opportunities to obtain the data it needs, such as by proposing a revision to the North American Industry Classification System. We continue to believe that the Subcommittee should implement our recommendation by taking such steps.

In written comments, OSTP stated it concurred with our fifth recommendation that the Subcommittee should examine approaches

other countries or regions are taking to see if there are any lessons learned that can be applied to the United States. OSTP stated that it looks forward to exploring the experiences and approaches of other countries and regions.

In its general comments, DOE expressed concerns that our evaluation of the federal government's approach to addressing critical materials supply issues is based largely on a nongeneralizable sample of critical materials experts and that it is not clear in the report that we considered how the composition of survey respondents could present significant bias in the results. DOE stated that a majority of the survey respondents fall under the 'Industry/Association' category and that representatives from industry could be expected to say that there is more the government can do to support domestic industries. As we state in the report, our survey results are not generalizable and only represent the views of those who responded. However, both the total number of experts from industry sampled (24) and the number of experts from industry that responded in the second round of the survey (19) represent about half of the experts we included in the survey. The remaining represent government experts (6 sampled and 5 who responded in the second round of the survey) and academic/nonprofit experts (16 sampled and 12 who responded in the second round of the survey). DOE's statement assumes that all of the industry respondents think government should do more—which may or may not be true. There could also be bias if the respondents' views differed from the views of nonrespondents. However, we do not know whether this is the case, and this type of bias can occur in any survey. Our findings are supported not only by our survey results, but also through our review of relevant documents and interviews with officials from government and industry in the United States and in other countries and regions. Therefore, we did not make any changes to the report as a result of DOE's comment.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, the Director of the Office of Science and Technology Policy, the Secretary of Commerce, and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or neumannj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix VI.

Sincerely yours,

John Neumann
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

This report (1) describes federal agencies' activities related to the supply of critical materials; (2) describes the approaches of selected countries and regions to address critical materials supply issues; and (3) evaluates the federal government's approach, such as coordination of activities, to addressing critical materials supply issues.

For our first and third objectives, we reviewed laws, regulations, and guidance related to the supply of critical materials, such as the National Materials and Minerals Policy, Research and Development Act of 1980 (1980 Act) and a law related to the Department of Defense's stockpiling of materials. We also collected and reviewed prior GAO reports on issues related to the federal effort to address the supply of critical materials, as well as congressional hearings, industry reports, and academic studies on the U.S. supply of critical materials. We also reviewed the charters of the Subcommittee on Critical and Strategic Mineral Supply Chains (Subcommittee), which is under the National Science and Technology Council's Committee on Environment, Natural Resources, and Sustainability.

To describe federal agencies' activities related to the supply of critical materials, we contacted the 20 federal agencies and Executive Office of the President organizations that are designated as members of the Subcommittee. These agencies and organizations are the Departments of Agriculture, Commerce, Defense, Education, Energy, Homeland Security, the Interior, Justice, Labor, State, and the Treasury, as well as the Environmental Protection Agency, National Aeronautics and Space Administration, National Science Foundation, Council on Environmental Quality, National Economic Council, National Security Council, Office of Management and Budget, Office of Science and Technology Policy, and Office of the U.S. Trade Representative (OSTP). We interviewed and obtained reports and analyses from officials from those agencies as appropriate. We also interviewed officials from a federal agency that was not designated as a member of the Subcommittee—the Department of Health and Human Services' National Institutes of Health—about its role in activities related to the supply of critical materials, as it relies on rare gases, for example, for research and medical applications.

To describe the approaches of selected countries and regions to address critical materials supply issues, we interviewed officials across government, academia, and industry from the European Union (EU), Japan, and Canada and obtained relevant documentation from officials. We also met onsite with EU officials in Brussels, Belgium, and Japanese officials in Tokyo. While in the EU, we also met with German officials in

Berlin and Bonn, to understand the impact of multinational planning on national laws and policies related to critical materials. We selected these countries and regions based on the efforts they have under way to address critical materials supply risks and our ability to collect information about those efforts.

To evaluate the federal government's approach to addressing critical materials supply issues, we developed and disseminated a two-stage, web-based survey to a nongeneralizable sample of 46 critical materials experts. The sample was selected with the goal of obtaining a balance of perspectives across the industrial, academic, and government sectors on the critical materials supply chain. We also identified subject matter areas relevant to the critical materials supply chain. Based on background research and interviews with experts, we identified the following relevant subject matter areas:

- Materials science—basic or applied research or experience related to materials that could be used in the production of advanced technologies, including methods for recycling materials.
- Industrial ecology—research or experience related to the flow of energy and materials through an industrial system, including, but not limited to, resource constraints and life cycle analysis.
- Mining and raw materials—research or experience related to extraction or processing of minerals or materials, including exploration and permitting for such activities.
- Markets and trade policy—research or experience related to commodity markets, supply and demand for materials, or trade policies that affect the flow of materials.
- Supply chain management—research or experience related to the management of an industry or government supply chain or the collection, dissemination, or analysis of information on material supply chains and the risk associated with them.
- Workforce issues—research or experience related to the adequacy of technically trained personnel in the fields of mining or material science.

To identify experts from the industrial, academic, and government sectors who are knowledgeable about matters involving the critical materials supply chain, the team used resources that included professional and government publications; participant lists of knowledge-sharing events, such as workshops, symposia, and conferences; recent congressional

testimonies related to critical materials issues; members of a federal advisory committee; and outreach to research and academic programs, trade associations, companies, and other industry groups. In addition, the team identified a number of potential experts based on interviews with federal agencies and other knowledgeable stakeholders conducted as part of the audit work for the engagement. We identified and reached out to more than 100 experts based on their expertise across the range of subject matter areas and sectors. Out of those experts we contacted, 49 expressed an interest in participating in the survey. In total, 47 experts (of 49 considered) were selected for participation in the survey. After the first round of the survey was sent out to all participants, one participant declined to participate and was removed from the list of participants resulting 46 experts. The makeup of the 46 experts consisted of 6 in government, 16 in academia and nonprofit organizations, and 24 in industry and trade group associations.[1] Table 4 shows the breakdown of experts' expertise across sectors.

Table 4: Distribution of Sample of Experts and Their Expertise across Sectors

		Expertise					
Sectors	**Number of experts**	**Materials science**	**Industrial ecology**	**Markets and trade policy**	**Mining and raw materials**	**Supply chain management**	**Workforce issues**
Academic/ nonprofit	16	4	2	5	6	5	4
Government	6	5	0	1	1	1	1
Industry/ association	24	6	1	8	14	10	1
Total	**46**	**15**	**3**	**14**	**21**	**16**	**6**

Source: GAO analysis of information obtained from experts. | GAO-16-699

Note: The sum of the rows is greater than the number of experts because some experts had multiple areas of expertise.

The first round of the survey was conducted from September 22, 2015, to October 30, 2015, and asked the experts to respond to five open-ended questions about the primary strengths and weaknesses of the U.S.

[1]One expert has held positions in both academia and in the federal government and was placed under the government sector category based on his current position in the federal government.

federal government's policies and activities related to critical materials and options for improving these efforts. Out of the 46 experts sampled for the survey, 33 responded to the survey, resulting in a response rate of 72 percent. The 33 who responded were experts who successfully submitted their conflict-of-interest forms and completed the electronic survey. After the experts completed the open-ended questions, we analyzed the responses to identify key issues raised by the experts. Based on those key issues raised by the experts, we identified topic categories related to the supply of critical materials. We then developed closed-ended questions for the second round of the survey in which we asked each expert to rate the ideas and other information that came from the first round of the survey. Two of the 33 respondents from the first round of the survey did not participate in the second round of the survey.

The second round of the survey was conducted from February 3, 2016, to March 4, 2016, and contained 30 questions. The first 29 questions were closed-ended questions, with many containing follow-up questions to further explore experts' responses. The last question was open-ended to capture experts' views on issues that had not been previously covered in the survey. Out of the 46 experts sampled for the second round of the survey, 36 responded, resulting in a response rate of 78 percent. We conducted follow-up phone calls around mid-February 2016 to participants who had not completed the survey, had not turned in their conflict-of-interest forms, or both. The 36 who responded to the survey were those experts who successfully submitted their conflict-of-interest forms and completed the electronic survey. Five of the 36 respondents who participated in the second round of the survey had not participated in the first round of the survey.

Because we selected a nongeneralizable sample of experts, their views are not generalizable to other experts in these subject matter areas, but their views can provide illustrative examples of critical materials supply issues. The quality of survey data can be affected by nonsampling error. Nonsampling error includes variations in how respondents interpret questions, respondents' willingness to offer accurate responses, and data collection and processing errors. In developing the web survey, we pretested draft versions of the instrument in December 2015 with 5 experts who later participated in the second round of the survey. On the basis of the pretests, we made revisions to the survey. We included steps in developing the survey and collecting, editing, and analyzing survey data, to minimize such nonsampling error. Furthermore, using a web-based survey also helped remove errors in our data collection effort. Allowing experts to enter their responses directly into an electronic

instrument automatically created a record for each expert in a data file and eliminated the errors associated with a manual data entry process.

To determine the extent of collaboration among agencies that are members of the Subcommittee, we collected documents and interviewed officials in OSTP and other agencies that are Subcommittee members to obtain additional information on the federal approach, including efforts to coordinate federal activities. To evaluate the federal approach, including coordination, we compared federal efforts against the national policy outlined in the 1980 Act and key practices for interagency collaboration.[2] We reviewed the eight key practices for interagency collaboration based on which of the practices were most relevant to the operations of the Subcommittee. The key practices for interagency collaboration are among the options for reducing or better managing fragmentation to improve the efficiency of federal programs and more effectively achieve their objectives. We identified all but one of the key practices (reinforce individual accountability for collaborative efforts through performance management systems) as relevant to the Subcommittee's functions.

We conducted this performance audit from March 2015 to September 2016 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[2]GAO, *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies*, GAO-06-15 (Washington, D.C.: Oct. 21, 2005).

Appendix II: Results of Selected U.S. Critical Materials Assessments

Table 5 provides information on the results of selected criticality assessments that have been conducted on a variety of materials that are important to U.S. economic and national security interests.

Table 5: Results of Selected Critical Materials Assessments for U.S. Economic and National Security Interests

	Materials identified as critical or potentially critical	National Academies of Sciences, Engineering, and Medicine (2008)[a]	Department of Energy (2010)[b]	Department of Energy (2011)[c]	Department of Defense (2015)[d]	National Science and Technology Council Subcommittee on Critical and Strategic Mineral Supply Chains (2016)[e]
Rare earth elements	Cerium	Yes	No	No	No	Yes
	Dysprosium	Yes	Yes	Yes	No	Yes
	Erbium	Yes	No	No	No	Yes
	Europium	Yes	Yes	Yes	Yes	Yes
	Gadolinium	Yes	No	No	No	Yes
	Holmium	Yes	No	No	No	Yes
	Lanthanum	Yes	No	No	Yes	Yes
	Lutetium	Yes	No	No	No	Yes
	Neodymium	Yes	Yes	Yes	No	Yes
	Praseodymium	Yes	No	No	No	Yes
	Promethium	Yes	No	No	No	Yes
	Samarium	Yes	No	No	No	Yes
	Scandium	Yes	No	No	No	No
	Terbium	Yes	Yes	Yes	No	Yes
	Thulium	Yes	No	No	No	Yes
	Ytterbium	Yes	No	No	No	Yes
	Yttrium	Yes	Yes	Yes	No	Yes
Platinum group metals	Iridium	Yes	No	No	No	Yes
	Osmium	Yes	No	No	No	No
	Palladium	Yes	No	No	No	No
	Platinum	Yes	No	No	No	No
	Rhodium	Yes	No	No	No	Yes
	Ruthenium	Yes	No	No	No	Yes
Other materials	Aluminum oxide, fused crude	No	No	No	Yes	No
	Antimony	No	No	No	Yes	Yes
	Beryllium	No	No	No	Yes	No
	Bismuth mine production	No	No	No	No	Yes
	Boron carbide	No	No	No	Yes	No

Materials identified as critical or potentially critical	National Academies of Sciences, Engineering, and Medicine (2008)[a]	Department of Energy (2010)[b]	Department of Energy (2011)[c]	Department of Defense (2015)[d]	National Science and Technology Council Subcommittee on Critical and Strategic Mineral Supply Chains (2016)[e]
Carbon fiber (seven types)	No	No	No	Yes	No
Chlorosulfonated polyethylene	No	No	No	Yes	No
Cobalt mine production	No	No	No	No	Yes
Indium	Yes	Yes	No	No	No
Ferromolybdenum	No	No	No	No	Yes
Germanium	No	No	No	Yes	Yes
Magnesite	No	No	No	No	Yes
Magnesium	No	No	No	Yes	No
Manganese	Yes	No	No	Yes	No
Mercury	No	No	No	No	Yes
Mica	No	No	No	No	Yes
Monazite	No	No	No	No	Yes
Niobium	Yes	No	No	No	No
Silicomanganese	No	No	No	No	Yes
Silicon carbide fiber, multifilament	No	No	No	Yes	No
Tungsten	No	No	No	Yes	Yes
Tungsten-rhenium alloy	No	No	No	Yes	No
Vanadium	No	No	No	No	Yes
Yttrium oxide	No	No	No	Yes	No

Source: GAO summary of U.S. critical materials assessments. | GAO-16-699

[a]National Research Council, *Minerals, Critical Minerals, and the U.S. Economy* (Washington, D.C.: 2008). This report examined 11 candidate minerals for criticality. Until May 2016, the National Academies of Sciences, Engineering, and Medicine was known as the National Research Council. The materials listed as critical or potentially critical in this appendix are the five minerals or mineral groups that were determined to fall in or near the critical zone of the criticality matrix. The 2008 assessment considered the rare earth elements and platinum group metals, respectively, together as a group.

[b]Department of Energy, *Critical Materials Strategy* (Washington, D.C.: December 2010). This report examined the role of rare earth metals and other materials in the clean energy economy. The materials listed as critical or potentially critical in this appendix are the six that were found to have the greatest short-term and medium-term criticality.

[c]Department of Energy, *Critical Materials Strategy* (Washington, D.C.: December 2011). This report examined the role of rare earth metals and other materials in the clean energy economy and updated the Department of Energy's 2010 *Critical Materials Strategy*. The materials listed as critical or potentially critical in this appendix are the five that were found critical in the short and medium terms.

[d]Department of Defense, *Strategic and Critical Materials 2015 Report on Stockpile Requirements* (Washington, D.C.: January 2015). This report identifies strategic and critical materials used in defense, essential civilian, and essential industry applications. The materials listed as critical or potentially critical in this appendix are the 21 materials for which the National Defense Stockpile Program identified a net shortfall.

[e]National Science and Technology Council, Subcommittee on Critical and Strategic Mineral Supply Chains of the Committee on Environment, Natural Resources, and Sustainability, *Assessment of Critical Minerals: Screening Methodology and Initial Application* (Washington, D.C.: March 2016). This report applied an early warning screening methodology to 78 mineral resources and identified 17 as potentially critical. The rare earth elements are listed separately in the table above, but the assessment considered a subset of the rare earth elements—lanthanum through lutetium— together as a group. Therefore, the number of selected minerals in this column totals to more than 17.

Appendix III: Comments from the Office of Science and Technology Policy

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

August 18, 2016

Mr. Chris Murray
Assistant Director, Natural Resources and Environment
Government Accountability Office

Dear Mr. Murray:

Thank you for the opportunity to review and comment on the GAO's draft report, "Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials," (GAO-16-699).

We appreciate GAO's recognition of the successes of the National Science and Technology Council's Subcommittee on Critical and Strategic Mineral Supply Chains (the Subcommittee) and its member agencies, including the March 2016 report on *Assessment of Critical Minerals: Screening Methodology and Initial Application*. In the past several years, the Subcommittee and its member agencies have made significant progress towards identifying and addressing mineral supply risk.

Your recommendations for executive action by the Office of Science and Technology Policy, working with the Subcommittee and agency leadership, as appropriate, are listed below (*italics*) along with our comments:

- *To strengthen the federal approach to addressing critical materials supply issues through enhanced interagency collaboration, the Subcommittee should:*
    - *Agree on and clearly define the roles and responsibilities of member agencies and take steps to actively engage all relevant federal agencies in the Subcommittee's efforts;*
    - *Develop joint strategies that articulate common outcomes, and identify contributing agencies' efforts; and*
    - *Develop a mechanism to monitor, evaluate, and periodically report on the progress of member agencies' efforts.*

  To clarify, roles and responsibilities of member agencies are defined by their existing missions, as reflected in their activities and corresponding participation in the Subcommittee. The interagency discussions serve to further inform and coordinate these activities, and where equities of multiple agencies are involved the Subcommittee as a whole, under the guidance of its co-chairs, takes action such as in this spring's release of a criticality assessment methodology and earlier formal requests for the establishment of new trade codes with greater granularity regarding certain materials. Further specification of roles and responsibilities within the context of the Subcommittee is either redundant, if aligned with agency missions, or may raise confusion if not. Correspondingly, agencies have in place mechanisms to monitor, evaluate, and report on the progress of their efforts in support of their missions, and the Subcommittee reports directly to its parent Committee and in other ways (public documents) on its collective actions.

- *To broaden future applications of the early warning screening methodology, the Subcommittee should take the steps necessary to include potentially critical materials beyond minerals, such as developing a plan or strategy for prioritizing additional materials.*

Plans to address additional materials are under discussion as the Subcommittee evaluates feedback on the published assessment methodology; considerations include the perceived needs and the availability of suitable data. Other approaches may also be considered to add potentially critical materials that cannot be screened using the methodology because of data limitations or other factors.

- *To enhance the federal government's ability to facilitate domestic production of critical materials, we recommend that the Subcommittee examine approaches other countries or regions are taking to see if there are any lessons learned that can be applied to the United States.*

  We concur and look forward to exploring the experiences and approaches of other countries or regions.

We appreciate your thoughtful input as we continue our efforts in this domain.

Sincerely,

Tamara Dickinson

Tamara Dickinson
Principal Assistant Director for Environment and Energy,
Office of Science and Technology Policy; and
Co-Chair, Committee on Environment, Natural Resources, and
Sustainability of the National Science and Technology Council

Appendix IV: Comments from the Department of Commerce

THE DEPUTY SECRETARY OF COMMERCE
Washington, D.C. 20230

August 25, 2016

Mr. John Neumann
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Neumann:

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report titled *ADVANCED TECHNOLOGIES: Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials* (GAO-16-699).

We found the report to be informative and the recommendation for enhanced interagency collaboration and clarity in agency roles to be appropriate. We agree with the recommendations and will consult with other agencies in order to develop an action plan with details on implementation.

If you have any questions, please contact MaryAnn Mausser, GAO Liaison for the Department of Commerce, at (202) 482-8120.

Sincerely,

Bruce H. Andrews

Appendix V: Comments from the Department of Agriculture

USDA United States Department of Agriculture | Forest Service | Washington Office | 201 14th Street, SW Washington, DC 20250

File Code: 1420; 2800
Date: AUG 16 2016

Mr. John Neumann
Director, National Resources and Environment
U.S. Government Accountability Office
441 G Street NW
Washington, DC 20548

Dear Mr. Neumann:

The U.S. Department of Agriculture appreciates the opportunity to respond to the U.S. Government Accountability Office (GAO) draft report "Advanced Technologies: Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials, (GAO-16-699)." The USDA generally agrees with the draft report.

We support the subcommittee on Critical and Strategic Mineral Supply Chains, co-chaired by the Office of Science and Technology Policy, the Department of Energy (DOE), the Department of the Interior, as well as the work of the DOE Critical Mineral Institute. However, we agree there are limitations including limited engagement with industry and limited focus on domestic production.

Thank you again for the opportunity to review the draft report. If you have any questions, please contact Antoine L. Dixon, Chief Financial Officer, at 202-205-0429 or aldixon@fs.fed.us.

Sincerely,

THOMAS L. TIDWELL
Chief

Caring for the Land and Serving People

Printed on Recycled Paper

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

John Neumann, (202) 512-3841 or neumannj@gao.gov

Staff Acknowledgments

In addition to the contact named above, Chris Murray (Assistant Director), Darnita Akers, Martin Campbell, Antoinette Capaccio, Mackenzie Doss, Lorraine Ettaro, Cheryl Harris, Holly Hobbs, Jill Lacey, Dan C. Royer, Tind Shepper Ryen, Jerome Sandau, Alexandra Stone, Vasiliki Theodoropoulos, and Reed Van Beveren made key contributions to this report.

Appendix VII: Accessible Data

Agency Comment Letter

Text of Appendix III: Comments from the Office of Science and Technology Policy

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EXECUTIVE OFFICE OF THE PRESIDENT

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

WASHINGTON, D.C. 20502

August 18, 2016

Mr. Chris Murray

Assistant Director, Natural Resources and Environment

Government Accountability Office

Dear Mr. Murray:

Thank you for the opportunity to review and comment on the GAO's draft report, "Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials," (GA0-16-699).

We appreciate GAO's recognition of the successes of the National Science and Technology Council's Subcommittee on Critical and Strategic Mineral Supply Chains (the Subcommittee) and its member agencies, including the March 2016 report on Assessment of Critical Minerals: Screening Methodology and Initial Application. In the past several years, the Subcommittee and its member agencies have made significant progress towards identifying and addressing mineral supply risk.

Your recommendations for executive action by the Office of Science and Technology Policy, working with the Subcommittee and agency

leadership, as appropriate, are listed below (italics) along with our comments:

- To strengthen the federal approach to addressing critical materials supply issues through enhanced interagency collaboration, the Subcommittee should:
    - Agree on and clearly define the roles and responsibilities of member agencies and take steps to actively engage all relevant federal agencies in the Subcommittee's efforts;
    - Develop joint strategies that articulate common outcomes, and identify contributing agencies' efforts; and
    - Develop a mechanism to monitor, evaluate, and periodically report on the progress of member agencies' efforts.

To clarify, roles and responsibilities of member agencies are defined by their existing missions, as reflected in their activities and corresponding participation in the Subcommittee. The interagency discussions serve to further inform and coordinate these activities, and where equities of multiple agencies are involved the Subcommittee as a whole, under the guidance of its co-chairs, takes action such as in this spring's release of a criticality assessment methodology and earlier formal requests for the establishment of new trade codes with greater granularity regarding certain materials. Further specification of roles and responsibilities within the context of the Subcommittee is either redundant, if aligned with agency missions, or may raise confusion if not. Correspondingly, agencies have in place mechanisms to monitor, evaluate, and report on the progress of their efforts in support of their missions, and the Subcommittee reports directly to its parent Committee and in other ways (public documents) on its collective actions.

- To broaden future applications of the early warning screening methodology, the Subcommittee should take the steps necessary to include potentially critical materials beyond minerals, such as developing a plan or strategy for prioritizing additional materials.

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Plans to address additional materials are under discussion as the Subcommittee evaluates feedback on the published assessment methodology; considerations include the perceived needs and the availability of suitable data. Other approaches may also be considered to add potentially critical materials that cannot be screened using the methodology because of data limitations or other factors.

- To enhance the federal government's ability to facilitate domestic production of critical materials, we recommend that the Subcommittee examine approaches other countries or regions are taking to see if there are any lessons learned that can be applied to the United States.

We concur and look forward to exploring the experiences and approaches of other countries or regions.

We appreciate your thoughtful input as we continue our efforts in this domain.

Sincerely,

Tamara Dickinson

Principal Assistant Director for Environment and Energy, Office of Science and Technology Policy; and Co-Chair, Committee on Environment, Natural Resources, and Sustainability of the National Science and Technology Council

Text of Appendix IV: Comments from the Department of Commerce

Page 1

THE DEPUTY SECRETARY OF COMMERCE

Washington, D.C. 20230

August 25, 2016

Mr. John Neumann

Director, Natural Resources and Environment

U.S. Government Accountability Office

441 G Street, NW

Washington, DC 20548

Dear Mr. Neumann:

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report titled ADVANCED TECHNOLOGIES: Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials (GAO- 16-699).

We found the report to be informative and the recommendation for enhanced interagency collaboration and clarity in agency roles to be appropriate. We agree with the recommendations and will consult with other agencies in order to develop an action plan with details on implementation.

If you have any questions, please contact Mary Ann Mausser, GAO Liaison for the Department of Commerce, at (202) 482-8120.

Sincerely,

Bruce H. Andrews

Text of Appendix V: Comments from the Department of Agriculture

Page 1

USDA United States Department of Agriculture

Forest Service

Washington Office

201 14th Street, SW

Washington, DC 20250

File Code: 1420; 2800

Date: AUG 16 2016

Mr. John Neumann

Director, National Resources and Environment

U.S. Government Accountability Office

441 G Street NW

Washington, DC 20548

Dear Mr. Neumann:

The U.S. Department of Agriculture appreciates the opportunity to respond to the U.S. Government Accountability Office (GAO) draft report "'Advanced Technologies: Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials, (GA0-16-699)." The USDA generally agrees with the draft report.

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Thank you again for the opportunity to review the draft report. If you have any questions, please contact Antoine L. Dixon, Chief Financial Officer, at 202-205-0429 or aldixon@fs.fed.us.

Sincerely,

THOMAS TIDWELL

Chief

Accessible Text/Data Tables

Accessible Text for Highlights Figure: Selected Strengths and Limitations of Federal Critical Materials Activities

Strengths	Limitations
Existence of an interagency subcommittee to support interagency collaboration	Interagency collaboration is not consistent with selected key practices
U.S. Geological Survey information on mineral resources	Federal focus on only a subset of materials for assessing critical materials supply issues
Department of Energy's Critical Materials Institute	Limited focus on developing domestic resources

Strengths	Limitations
	Limited federal government engagement with industry stakeholders

Source: GAO analysis of expert survey and information collected from agency officials. | GAO-16-699

Accessible Text for Figure 1: Criticality Matrix Developed by the National Academies of Sciences, Engineering, and Medicine's Committee on Critical Mineral Impacts on the U.S. Economy

Impact of supply restriction
(importance of mineral)
Low Medium High

Supply risk
(availability and reliability of mineral supply)
Low Medium High

Mineral criticality
Mineral A Mineral B

Source: National Research Council, Minerals, Critical Minerals, and the U.S. Economy (Washington, D.C.: 2008). | GAO-16-699

Accessible Text for Figure 2: Materials Supply Chain

- Extraction
- Processing
- Components
- End-use applications
- Recycling and reuse

Source: Department of Energy, Critical Materials Strategy (Washington, D.C.: 2011). | GAO-16-699

Accessible Text for Figure 3: Federal Agencies' Activities to Identify and Assess Critical Materials Supply Risk

Assessing risk

Department of the Interior

Collects, analyzes, and disseminates information on the domestic and international supply of and demand for minerals. Helped lead the interagency development of a critical minerals screening methodology.

Department of Energy

Analyzes critical materials challenges in clean energy technologies and conducts supply and demand forecasting for critical isotopes. Helped lead the interagency development of a critical minerals screening methodology.

Department of Defense
Identifies availability of materials for the defense industrial base and estimates size of potential materials supply shortfalls using national emergency scenarios.

Department of Commerce
Analyzes the capabilities of the U.S. industrial base to support national defense. Convened industry roundtables on rare earth risks to U.S. manufacturers.

Department of Homeland Security
Analyzes foreign infrastructure upon which the U.S. depends, including elements of critical supply chains.

National Aeronautics and Space Administration
Analyzes critical materials supply chains, targeting applied challenges in support of space flight, planetary and earth exploration, and aeronautics/aviation.

Source: GAO analysis of information and documents collected from agency officials. | GAO-16-699

Accessible Text for Figure 4: Federal Agencies' Research Activities Related to Critical Materials Supply

Research

Department of Energy
Manages the Critical Materials Institute--a 5-year, $120 million effort aimed at finding ways to diversify supply, provide alternatives to existing materials, and improve recycling and reuse.

Department of Defense
Works on resolving the technical barriers to achieving a reliable supply chain for critical materials.

National Science Foundation
Funds critical materials research as a component within broader research programs, such as the Center for Resource Recovery and Recycling.

Department of the Interior
Supports research on nonfuel mineral resources.

Source: GAO analysis of information and documents collected from agency officials. | GAO-16-699

Accessible Text for Figure 5: European Innovation Partnership on Raw Materials

- Led by a steering group with 36 key stakeholders across government, academia, and industry.
- Steering group first met in February 2013.
- Selected targets to be achieved by 2020:
    - up to 10 pilot programs on exploration, mining, processing, and recycling for innovative production of raw materials;
    - substitutes for at least three applications of critical and scarce raw materials; and
    - network of research, education, and training centers on sustainable raw materials management.

Source: GAO summary of information on the European Innovation Partnership on Raw Materials. | GAO-16-699

Accessible Text for Figure 6: Japan's Materials Science Element Strategy

- Initial industry and academic collaboration started in 2007.
- Research and development hub started in 2012 and funded at 2 billion yen (U.S. $19 million) per year, for 10 years.
- Based on inter-disciplinary and cross-sectoral collaboration.
- Governed by an inter-ministry board to facilitate coordination between the Ministry of Education, Sports, Culture, Science and Technology, which funds basic science research, and the Ministry of Economy, Trade and Industry, which funds applied science research.

Source: GAO summary of information on Japan's Element Strategy. | GAO-16-699

Accessible Text for Figure 7: Canada's Major Projects Management Office

- The Major Projects Management Office provides guidance to project proponents and other stakeholders.
- It coordinates project agreements and timelines between federal departments and agencies.
- It tracks and monitors the progression of major resource projects through the federal regulatory review process.

Source: GAO summary of information on Canada's Major Projects Management Office. | GAO-16-699