U.S. DEPARTMENT OF ENERGY

CRITICAL MINERALS AND MATERIALS

U.S. DEPARTMENT OF ENERGY'S STRATEGY TO SUPPORT DOMESTIC CRITICAL MINERAL AND MATERIAL SUPPLY CHAINS

(FY 2021–FY 2031)

Executive Summary

Critical minerals and materials are used in many products important to the United States economy and national security. Thus, the assured supply of critical minerals and materials and the resiliency of their supply chains are essential to the economic prosperity and national defense of the United States. Of the 35 mineral commodities identified as critical in the list[1] published in the Federal Register by the Secretary of the Interior, the United States lacks domestic production of 14[2] and is more than 50 percent import-reliant for 31.[3] This import dependence puts industrial supply chains, United States companies, and material users at significant risk.

Recognizing the critical minerals and materials challenge facing the United States, President Trump, on December 20, 2017, issued Executive Order 13817 (E.O. 13817), *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*,[4] which identified actions to reduce our Nation's reliance on imports, preserve our leadership in technological innovation, support job creation, and improve national security and the balance of trade. The Department of Commerce published a report required by E.O. 13817 on June 4, 2019.[5] The report established a coordinated Federal Strategy to address critical mineral and material supply chain challenges through calls to action and specific recommendations focused on research and development, industrial supply chain development, mapping improvements, permitting, and workforce development.

To advance further action on mitigating the national critical minerals and materials challenge, on September 30, 2020, President Trump issued Executive Order 13953 (E.O. 13953), *Addressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries*,[6] which directed agencies to examine potential authorities and prepare agency-specific plans to improve the mining, processing, and manufacturing of critical minerals and materials.

To meet this Order, the Department of Energy (DOE) has prepared this strategy, which describes the objective, goals, and organizational methods DOE will employ across the entire enterprise. DOE's crosscutting strategy for addressing critical minerals and materials is supported by three key pillars: diversifying supply, developing substitutes, and improving reuse and recycling.

The strategy has been developed with insights gleaned from current extensive internal and external coordination activities. DOE was a key agency in the development of the Federal Strategy on Critical Minerals and is the co-chair of the National Science & Technology Council (NSTC) Critical Minerals Subcommittee. In developing and executing critical minerals and materials work, DOE has regularly interacted with and across interagency partners, and coordinates work through the White House Executive Office of the National Security Presidential Memoranda (NSPM) process. In particular, DOE has forged a strong working relationship with the Departments of Defense, Interior, Commerce, and State, and has established strong international partnerships on the topic of critical minerals with Canada, Australia, the European Union, and Japan.

Vision

The Department of Energy will be an essential source of science, technology, and engineering solutions for re-establishing U.S. competitiveness in critical mineral and material supply chains

[1] *Aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, the rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium. Final List of Critical Minerals 2018, U.S. Department of the Interior, 83 Fed. Reg. 23295, 2018, https://www.govinfo.gov/content/pkg/FR-2018-05-18/pdf/2018-10667.pdf*

[2] *Mineral Commodity Summaries 2018, U.S. Geological Survey, 2018, https://doi.org/10.3133/70194932*

[3] *Final List of Critical Minerals 2018, U.S. Department of the Interior, 83 Fed. Reg. 23295; 2018, https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018*

[4] *Executive Office of the President, 2017, https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf*

[5] *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce 2019 https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

[6] *Executive Office of the President, 2020, https://www.govinfo.gov/content/pkg/FR-2020-10-05/pdf/2020-22064.pdf*

Strategic Goals

1. Foster scientific innovation and develop technologies that will ensure resilient and secure critical mineral and material supply chains independent of resources and processing from foreign adversaries.
2. Catalyze and support private sector adoption and capacity for sustainable domestic critical mineral and material supply chains.
3. Build the long-term minerals and materials innovation ecosystem—fostering new capabilities to mitigate future critical mineral and material supply chain challenges.
4. Coordinate with international partners and allies and other Federal agencies to diversify global supply chains and ensure the adoption of best practices for sustainable mining and processing.

Principles

These four goals are underpinned by four foundational principles:

- DOE's critical minerals and materials efforts will be balanced across three pillars: diversify supply chains, develop substitutes, improve reuse and recycling.

- DOE will coordinate and collaborate across program offices; leverage DOE's National Laboratories; and increase industrial engagement and partner with foreign allies to strategically address these mineral and material supply chains challenges.

- DOE will use its broad capabilities and unique authorities to explore and develop sustainable critical mineral and material supply chains.

- DOE's critical mineral and material efforts will be informed and prioritized by criticality and supply chain analysis. These analyses will guide DOE's strategy and activities to address key supply vulnerabilities.

This strategy also outlines a series of programmatic objectives and lines of action that DOE will pursue to support the requirements and needs of other U.S. agencies and industry, consistent with the strategic goals and principles.

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The DOE Strategy to Ensure Secure and Reliable Supplies of Critical Minerals

Executive Orders have catalyzed coordinated efforts, across the Federal Government, on critical minerals. In the most recent, on September 30, 2020, the President signed Executive Order 13953 (E.O. 13953), A*ddressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries.*

E.O. 13953 requires that DOE:

- Within 30 days of the date of the Executive Order, submit a report to the President that identifies all legal authorities and appropriations that the agency can use to meet the goals identified in the Executive Order (see Appendix A);

- Within 60 days of the date of the Executive Order, submit the agency's strategy for using the legal authorities and appropriations identified to meet the goals of the Executive Order. The report shall explain how the agency's activities will be organized and how it proposes to coordinate relevant activities with other agencies;

- Within 30 days of the date of the Executive Order, develop and publish guidance clarifying the extent to which projects that support domestic supply chains for minerals are eligible for loan guarantees pursuant to Title XVII of the Energy Policy Act of 2005, as amended, and fund awards and loans pursuant to the Advanced Technology Vehicles Manufacturing (ATVM) incentive program established by section 136 of the Energy Independence and Security Act of 2007, as amended;

- Within 30 days of the date of the Executive Order, review its regulations (including any preambles thereto) interpreting Title XVII and the ATVM statute, including the regulations published at 81 Fed. Reg. 90,699 (Dec. 15, 2016) and 73 Fed. Reg. 66,721 (Nov. 12, 2008), and identify all such regulations that may warrant revision or reconsideration in order to expand and protect the domestic supply chain for minerals (including the development of new supply chains and the processing, remediation, and reuse of materials already in interstate commerce or otherwise available domestically);

- Within 90 days of the date of the Executive Order, propose for notice and comment a rule or rules to revise or reconsider any such regulations for this purpose, as appropriate and consistent with applicable law; and

- Examine available authorities of DOE and identify any such authorities that could be used to accelerate and encourage the development and reuse of historic coal waste areas, materials on historic mining sites, and abandoned mining sites for the recovery of critical minerals.

This Department strategy (DOE Strategy) fulfills the immediate planning direction under E.O. 13953 and lays out future actions to guide the agency forward. The authorities gathered and identified in Appendix A informed the writing of this strategy and all of the strategic goals and objectives delineated herein. Further, the new guidance and rules published by DOE in support of increased access to the DOE Loan Programs for critical minerals and materials projects constitute an important tool to support private sector innovators and are therefore an integral element of this strategy. DOE is publishing and disseminating the strategy required by E.O. 13953 to better communicate its vision for DOE's essential role in solving the critical minerals and materials challenges facing the United States over the coming decade.

The Federal Strategy and DOE's Role in Execution

The Federal Strategy to *Ensure Secure and Reliable Supplies of Critical Minerals* (Federal Strategy) was released in June 2019 by the Department of Commerce (DOC) in response to Executive Order (E.O.) 13817. The Federal Strategy was written by the NSTC Critical Minerals Subcommittee. The Federal Strategy provides the umbrella framework for the goals of agencies and is structured around six Calls to Action to address key critical mineral supply chain challenges. Each Call to Action has several recommendations articulated. The specific Calls to Action are:

Calls to Action	Goals directly related to DOE
1. Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains (DOE Lead)	Coordinate R&D strategy across critical mineral supply chains; Increase U.S. private industry investment in innovation and improve technology transfer
2. Strengthen America's Critical Mineral Supply Chains and Defense Industrial Base (NNSA Co-Lead)	Understand and support the critical minerals industry and related supply chain; Leverage expertise from DOE stakeholders
3. Enhance International Trade and Cooperation Related to Critical Minerals	Increase international exchanges with partner nations
4. Improve Understanding of Domestic Critical Mineral Resources	Enable commodity-specific mitigation strategies; Encourage the use of secondary and unconventional sources of critical minerals
5. Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes	N/A; Call to Action 5 is a Department of the Interior focused effort in response to a Secretarial order
6. Grow the American Critical Minerals Workforce	Bolster education; Promote interdisciplinary collaboration among material and chemical science, computer science, and related disciplines to modernize the minerals supply sector industry

Among the Federal agencies, DOE leads the efforts on Call to Action 1 and co-leads Call to Action 2, while playing a key role in other aspects of the Federal Strategy, including to increase international exchanges with partner nations; enable commodity-specific mitigation strategies; and encourage the use of secondary and unconventional sources of critical minerals and materials. Finally, DOE will, within the framework of this Strategy, increase its role in Call to Action 6, growing the American critical minerals workforce. Many of the goals and objectives outlined in this DOE Strategy link directly to recommendations from the umbrella Federal Strategy and fit within its framework.

Current DOE Activities

For decades, DOE has been a leader in addressing critical mineral and material supply chain challenges, with efforts increasing in scope and magnitude recently. Over the years, there have been significant investments across the three pillars of: Diversifying Supply Chains, Developing Substitutes, and Improving Reuse and Recycling. For example:

- Diversifying Supply: DOE has funded fundamental science, technology development, and bench- and small-scale production of critical minerals and materials, such as producing rare earth elements (REEs) from unconventional sources (e.g., coal and coal byproducts), improving rare earth separation processes, and developing new uses for co-products (e.g., cerium from rare earth element mining);[7,8,9,10]

- Develop Substitutes: DOE has made significant advances in developing new magnet alloys or new phosphor materials to the need for reduce rare earth elements; advanced the basic science of catalysis to reduce demand for platinum-group metals; introduced new advanced manufacturing methods like additive manufacturing; and new components and systems to eliminate the need for critical materials (e.g., new motor or generator topologies); and

- Improve Reuse and Recycling: DOE has advanced the disassembly and recovery of rare earth magnets from hard disk drives; introduced manufacturing methods to reuse recycled magnets; and used chemical recovery of REEs from magnets and noble metals from catalysts.

There has been significant activity across the Department to address key supply chain challenges for critical minerals and materials. Below are short summaries from representative DOE program offices.

The Office of Fossil Energy (FE) Minerals Sustainability Division was established in 2020. This new Division will support DOE in its research, design, and development (RD&D) and applied engineering efforts five areas: (1) Assessment and prediction of resource potential and enabling technology development (drones, dynamic simulations, real time sensing and analytics, and micro drilling technologies); (2) Conventional and novel resource extraction to enable recovery of currently unrecoverable minerals; (3) Extraction from abandoned mine residuals and remediation of existing sites while maximizing environmental controls; (4) Mineral processing through extractive metallurgy and reduction and alloying that maximize production of mineral feedstocks and advance U.S. industrial, energy, and other sectors; and (5) Mineral processing through extractive metallurgy and reduction and alloying technology pilots necessary to enable commercial production while minimizing land disturbance and maximizing environmental stewardship. FE has been conducting early-stage and applied research on extracting, separating, and recovering critical minerals and rare earth elements from domestic coal-based resources since 2014. This has resulted in the design, construction, and operation of bench-and small pilot-scale facilities producing mixed rare earth oxides (MREO), salts (MRES), and other critical minerals. Building on the success of the research projects, FE is beginning move to the next phase of scale-up, beginning with 13 feasibility studies for the development of systems that can produce one to three tonnes per day of MREO or MRES and critical minerals. These facilities will be evaluating the co-production of other critical minerals and materials such as cobalt (Co), manganese (Mn), lithium (Li), and potentially aluminum (Al), zinc (Zn), germanium (Ge), and gallium (Ga).[11] Through the Carbon Ore Rare Earth and Critical Minerals Initiative (CORE-CM), FE will develop and implement strategies that enable U.S. basins to reach the full potential for carbon ores and critical minerals, including establishing multiple regional innovation centers. The innovation

[7] *Aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, the rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium*

[8] *Mineral Commodity Summaries 2018, U.S. Geological Survey, 2018, https://doi.org/10.3133/70194932*

[9] *Final List of Critical Minerals 2018, U.S. Department of the Interior, "Final List of Critical Minerals 2018," 83 Fed. Reg. 23295, 2018, https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018*

[10] *Minerals are naturally occurring inorganic materials. The term critical mineral is typically considered to include minerals and the materials that are processed from those minerals. DOE often uses the term critical materials, while the White House and Congress typically uses the term critical minerals, and are viewed as interchangeable. Rare earth elements are examples of critical minerals and have been a significant focus of DOE's investments.*

[11] *DOE Awards $1.95M for Conceptual Designs that Extract Critical Minerals and Rare Earth Elements from Coal Sources, Office of Fossil Energy, U.S. Department of Energy, 2020, https://www.energy.gov/fe/articles/doe-awards-195m-conceptual-designs-extract-critical-minerals-and-rare-earth-elements*

centers will be located in different regions of the country to address region-specific geology, geography, and policy issues.[12]

The Office of Energy Efficiency and Renewable Energy (EERE) works across three sectors: energy efficiency, renewable power, and transportation. In the area of critical minerals, the Technology Offices in these three sectors work to mitigate supply chain risk through research and development (R&D) to diversify supply, develop alternatives, improve reuse and recycling, and enable fundamental crosscutting research. These supply chain risk mitigation strategies are directly aligned with the Federal Strategy. The EERE R&D portfolio is quite extensive, covering the entire critical minerals and material supply chain from resource assessment through value-added manufacturing (including separation and production of metals, alloys, and value-added products) to system integration and including reuse, recycling, and more efficient use; safety, human, and environmental health considerations; and technology transition. Through coordination across EERE, supply chains for critical materials in magnets, energy storage, electronics, and lighting are addressed. The EERE efforts related to critical minerals and REEs include, but are not limited to: Critical Materials Institute (CMI), a DOE Energy Innovation Hub led by Ames Laboratory[13]; ReCell Lithium Battery Recycling R&D Center at Argonne National Laboratory (ANL)[14]; Lithium-Ion Battery Recycling Prize[15]; Commercialization of Electric Vehicle Batteries ; Building Energy Efficiency Frontiers & Innovation Technologies (BENEFIT)[17]; Geoscience Data Acquisition for Western Nevada (Geo-DAWN)[18]; heavy REE-free traction motors for electric vehicles (EVs)[19]; and recovering Critical Minerals from geothermal brines and seawater.[20] In (FY) 2021, EERE will launch a number of research and development projects that focus on pilot and demonstration of separation and processing of critical minerals, as well as next generation extraction, separation, and processing technologies for critical materials.[21] EERE also plans to launch a $4 million Geothermal Lithium Prize that will award research that overcomes critical technological barriers currently inhibiting our ability to produce cost-effective, domestic lithium from geothermal brines.

Advanced Research Projects Agency-Energy (ARPA-E) seeks to enhance the pace of energy innovation by incorporating biological REE and other critical metal accumulation processes through its biomining program. The biomining program was initiated in November 2020 with six projects at universities and federally funded research and development centers.[22] The ARPA-E Mining Incinerated Disposal Ash Streams (MIDAS) program aims to recover critical metals and other valuable elements from municipal solid waste incineration ash.[23] With proposed solutions targeting the recovery of 95 percent of all critical metals and 90 percent of other metals, the MIDAS program has the potential to transform municipal solid waste into a reliable source for recovered critical materials. An additional five projects will be launched.

The Office of Science (SC), through the Basic Energy Sciences (BES) program, supports critical materials research in two primary areas: (1) Advancing the

[12]*Department of Energy Announces $122 Million for Regional Initiative to Produce Rare Earth Elements and Critical Minerals, Office of Fossil Energy, U.S. Department of Energy, 2020, https://www.energy.gov/articles/department-energy-announces-122-million-regional-initiative-produce-rare-earth-elements-and*

[13]*Critical Materials Institute, Ames Laboratory, U.S. Department of Energy https://www.ameslab.gov/cmi. CMI has 35 active projects ranging from improved beneficiation of rare earth concentrates from bastnaesite ore, to reduction of metals, production of alloys and value-added products like magnets, to criticality assessment and the development of life cycle assessment and techno-economic analysis tools, and evaluation of the environmental impacts of novel processes.*

[14]*ReCell Center, Argonne National Laboratory, U.S. Department of Energy https://recellcenter.org/. ReCell conducts research in four areas, including direct recycling of cathodes, recovery of other materials like graphite and electrolytes, design for sustainability to transition to cell and battery design with reuse and recycling in mind, and characterization, such as materials and thermal analysis.*

[15]*American Made Battery Recycling Prize, U.S. Department of Energy, https://americanmadechallenges.org/batteryrecycling/. The Battery Prize focuses on addressing the challenge of getting batteries from users at end of life to recyclers—including collection, separation and sorting, safe transportation, and storage, and solving the complex reverse logistics challenges of bringing all these pieces together.*

[16]*Research Plan to Reduce, Recycle, and Recover Critical Materials in Lithium-Ion Batteries, Vehicle Technologies Office, U.S. Department of Energy, 2019, https://www.energy.gov/sites/prod/files/2019/07/f64/112306-battery-recycling-brochure-June-2019%202-web150.pdf*

[17]*Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT), DE-FOA-0002196, U.S. Department of Energy, 2020, https://www.energy.gov/articles/department-energy-announces-80-million-innovative-building-technologies-and-practices*

[18]*USGS and EERE: Collaborating to Strengthen America's Energy and Resource Independence, 2020, https://www.energy.gov/eere/articles/usgs-and-eere-collaborating-strengthen-america-s-energy-and-resource-independence. Geoscience Data Acquisition for Western Nevada is an Interagency agreement between DOE EERE &.*

[19]*The Vehicle Technologies Office funded two projects in FY 2020 to advance low cost electric traction drive systems that use no heavy rare earth materials, https://www.energy.gov/sites/prod/files/2020/07/f76/FY20_VTO_2197_selections_table-for_release.pdf*

[20]*Low Temperature & Coproduced Resources, U.S. Department of Energy, https://www.energy.gov/eere/geothermal/low-temperature-coproduced-resources*

[21]*https://eere-exchange.energy.gov/FileContent.aspx?FileID=e4b7fbb9-c557-4098-ad9d-dccfdb384bd3*

[22]*Funding Opportunity No. DE-FOA-0001953, Advanced Research Projects Agency – Energy, 2018, https://arpa-e-foa.energy.gov/FileContent.aspx?FileID=a5f0b84f-5f5f-46ac-abbc-df837c6c9290*

[23]*Waste Into X and the MIDAS Touch, Advanced Research Projects Agency – Energy, https://arpa-e.energy.gov/news-and-media/blog-posts/waste-x-and-midas-touch*

understanding of the role of rare earth, platinum group, and other critical elements in the determination of the properties of materials and molecules at length scales ranging from electronic interaction distances to atomic and microstructural scales; and (2) Separation science to enhance the chemical processing of critical elements. This research focuses on improving the efficiency of both the use of the critical elements and their extraction from natural occurrences, mine tailings, chemical process solutions, and recycled sources. It also seeks to reduce the reliance on critical elements by discovering substitute materials with similar or even enhanced chemical, catalytic, electrical, magnetic, and optical properties. In addition, BES operates major x-ray, neutron, and nanoscience user facilities that provide advanced characterization capabilities to the scientific community. BES also supports computational and theoretical activities such as SciDAC and Computational Materials and Chemical Sciences projects that produce exascale-level open-source community codes for predictive design of processes and materials. BES research was significantly expanded in 2020 with the announcement of five new DOE National Laboratory-led awards aimed at ensuring a stable U.S. supply of REEs.[24]

The Office of Nuclear Energy (NE) is focused on the development and demonstration of advanced reactor designs that will rely on a variety of critical minerals and materials, such as helium coolants, graphite structures and moderators, advanced moderators using zirconium and yttrium hydrides, and molten salt coolants using beryllium and lithium. Many critical minerals and materials are also essential for continued operation of the existing nuclear fleet that supplies nearly 55 percent of our nation's carbon free energy. And because existing and advanced reactors rely on a predictable and stable supply of enriched uranium for fuel, NE is focused on the development of technologies to separate and recycle uranium, as well as supporting domestic uranium production, conversion, and enrichment. NE will survey the existing fleet and advanced reactor communities to determine a list of critical materials and quantities to inform an evaluation of the full supply chain, plans to conduct R&D activities to reduce the lifecycle costs of uranium production, and looks to establish a national uranium reserve. NE supports supply chain development through a variety of private-public partnerships with industry, including the recently announced Advanced Reactor Demonstration Funding Opportunity Announcement awards[25] and the ongoing U.S. Industry Opportunities for Advanced Nuclear Technology Development Funding Opportunity.[26]

The Office of Technology Transitions (OTT) provides technical supports to the CMI established by EERE. OTT will build on their support for CMI to produce business-informed technology roadmaps and market development/deployment plans that help position CMI-developed technologies for licensing and commercialization in the United States.[27] OTT will train key project personnel in decision/opportunity framing competencies, so that the learned skills can be applied to enhance commercialization opportunities from the Laboratories' greater technology portfolios.

International

DOE also has significant engagements with international allies on critical minerals and materials. DOE plays a key role in the United States' bilateral critical minerals partnership with Canada. Through the interaction, partners will leverage resource information, private sector engagement, and multilateral fora to secure critical minerals for key industry and defense. Cooperation under the U.S.-Canada Critical Minerals Action Plan will capture joint engagements such as research and development, supply chain modeling, and support for industry.[28]

The Department also participates with other U.S. Government agencies in a bilateral agreement with Australia. The United States-Australia Critical Minerals Working Group (organized by the State Department) held meetings in 2020 to begin discussions on how the partnership can strengthen global supply chains.[29] Notably, Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) expressed interest in initiating discussions on future research

[24]*DOE Awards $20 Million for Research on Rare Earth Elements, Office of Basic Energy Sciences, U.S. Department of Energy, 2020, https://www.energy.gov/articles/doe-awards-20-million-research-rare-earth-elements*

[25]*Energy Department's Advanced Reactor Demonstration Program Awards $30 Million in Initial Funding for Risk Reduction Projects, Office of Nuclear Energy, U.S. Department of Energy, 2020, https://www.energy.gov/ne/articles/energy-department-s-advanced-reactor-demonstration-program-awards-30-million-initial*

[26]*U.S. Industry Opportunities for Advanced Nuclear Technology Development Funding Opportunity Announcement Number DE-FOA-0001817, U.S. Department of Energy, 2020, https://www.id.energy.gov/NEWS/FOA/FOAOpportunities/FOA.htm*

[27]*Ames Lab accelerates commercialization of CMI technologies through Innovation Partnerships Program, Ames Laboratory, U.S. Department of Energy, 2020, https://www.ameslab.gov/news/ames-lab-accelerates-commercialization-of-cmi-technologies-through-innovation-partnerships*

[28]*United States and Canada Finalize Action Plan on Critical Minerals Cooperation, U.S. Department of State, 2020, https://www.state.gov/united-states-and-canada-finalize-action-plan-on-critical-minerals-cooperation/*

and development cooperation among each countries' respective laboratory critical minerals efforts.

Importantly, DOE leads the federal government in a trilateral partnership with the European Union and Japan. Through the decade of engagements, the trilateral partnership has enabled exchanges on technical innovation and critical materials progress. Recently, the trilateral partners have agreed to expand the participation to include Canada and Australia and to expand the technical exchanges to include more policy discussion.

Interagency

DOE plays a leadership role in the Federal Government's efforts in the area of critical minerals and materials, such as the National Science and Technology Council (NSTC), which convenes Federal science and technology leaders in committees, subcommittees, and working groups to establish clear national goals for policy and investment. The NSTC committee on Homeland and National Security coordinates interagency work related to, but not limited to, nuclear R&D defense critical infrastructure security and resilience, and oversees the Critical Mineral Subcommittee. The NSTC Critical Mineral Subcommittee provides assistance and expertise to the NSTC on policies, procedures, and plans relating to identification and forecasting of mineral criticality, and risk mitigation in the procurement and downstream processing of minerals identified as or forecasted to become critical. It is responsible for implementation of the Federal Strategy requested by the President under E.O. 13817 on critical mineral supply chains. DOE has served as a co-chair of the subcommittee since its establishment alongside the Office of Science and Technology Policy (OSTP) and the United States Geological Survey (USGS). Through the subcommittee, DOE collaborates and coordinates with other executive branch agencies, including the Department of Defense, Commerce, Interior, Homeland Security, Education, State, Justice, Agriculture, Transportation, Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), International Trade Commission, National Science Foundation (NSF) and the Executive Office of the President.

[29] *United States and Australia Make Progress on Improving Critical Mineral Security, U.S. Department of State, 2020, https://www.state.gov/united-states-and-australia-make-progress-on-improving-critical-mineral-security/*

The DOE Strategy

Vision

The Department of Energy will be an essential source of science, technology, and engineering solutions for re-establishing U.S. competitiveness in critical mineral and material supply chains

To fulfill this vision, DOE will apply its core mission competencies and capabilities to help the Nation achieve these strategic goals:

1. Drive scientific innovation and develop technologies that will ensure resilient and secure critical mineral and material supply chains independent of resources and processing from foreign adversaries.

Objective 1.1: Coordinate on-going R&D activities and capabilities;

Objective 1.2: Develop coordinated R&D roadmap;

Objective 1.3: Identify future R&D opportunities through public-private partnerships; and

Objective 1.4: Identify potential collaboration opportunities in R&D with interagency and international partners.

2. Catalyze and support private sector adoption and capacity for sustainable domestic critical mineral and material supply chains.

Objective 2.1: Coordinate on-going technology transition and transfer activities and capabilities;

Objective 2.2: Develop future opportunities for improved adoption and capacity;

Objective 2.3: Engage and support key stakeholders; and

Objective 2.4: Enable technology transfer mechanisms.

3. Build the long-term minerals and materials innovation ecosystem—fostering new capabilities to mitigate future critical mineral and material supply chain challenges.

Objective 3.1: Develop a robust criticality analysis framework;

Objective 3.2: Improve and enable mapping of critical mineral and material deposits; and

Objective 3.3: Grow the American critical mineral and material workforce.

4. Coordinate with international partners and allies, and other Federal agencies, to diversify global supply chains and ensure the adoption of best practices for sustainable mining and processing.

Objective 4.1: Increase international exchanges and activate multilateral fora;

Objective 4.2: Coordinate across the interagency; and

Objective 4.3: Collaborate with international partners to establish global industry standards.

Principles

- DOE's critical minerals and materials efforts will be balanced across three pillars: diversify supply chains, develop substitutes, improve reuse and recycling.

- DOE will coordinate and collaborate across program offices; leverage DOE's National Laboratories; and increase industrial engagement and partner with foreign allies to strategically address these mineral and material supply chains challenges.

- DOE will use its broad capabilities and unique authorities to explore and develop sustainable critical mineral and material supply chains.

- DOE's critical mineral and material efforts will be informed and prioritized by criticality and supply chain analysis. These analyses will guide DOE's strategy and activities to address key supply vulnerabilities.

The vision was crafted to enable a cohesive innovation pipeline for DOE in order to strengthen DOE's impact on the development of secure domestic supply chains. In establishing an integrated and coordinated R&D portfolio (Goal 1), combined with a focused technology transition and transfer effort (Goal 2), DOE will catalyze the progression of technologies from fundamental science to commercial deployment. At the same time, DOE will work to identify and mitigate future supply chain issues (Goal 3). To accomplish all of this, DOE needs to work with interagency and international partners (Goal 4).

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Methodology (Developing the DOE Strategy)

This DOE Critical Minerals and Materials Strategy (DOE Strategy) was developed using an internal coordination process that involved DOE Headquarters functional and program offices, working through the DOE Critical Minerals and Materials Coordination Group (CMMCG). This Group is chaired by the DOE Office of Strategic Planning and Policy (OSPP), which is the senior policy office for the Secretary of Energy and responsible for, inter alia, the overall strategic planning of DOE's role in U.S. critical minerals and materials efforts.

National critical minerals priorities are established by Executive Orders and Presidential Memorandum, which result from a White House-led interagency policy coordination process under the NSTC, OSTP, and the National Security Council. Working from these national policy documents, the DOE OSPP led development and coordination of this DOE Strategy.

The process was also informed by current activities being implemented by DOE, elements of the Federal Strategy, and the Executive Orders 13817 and 13953. DOE actively participates in U.S. interagency working groups and committees on critical minerals and materials, and this plan and related programmatic actions align with the goals and guidance created through these interagency interactions.

Implementation

In implementing the DOE Strategy, DOE is identifying and developing coordinated programmatic activities across the complex, which will support the Federal Government's progress towards its critical strategic goals. For instance, DOE will make use of different programs and partnership mechanisms, including DOE program-directed activities, DOE-sponsored cross-discipline science and technology (S&T) initiatives, externally sponsored National Laboratory projects (called Strategic Partnership Projects), National Laboratory-directed research & development activities, and technology transition and private sector partnership initiatives (e.g., XLab Innovation Summits and Cooperative R&D Agreements). Most of the DOE programs managing critical minerals and materials work report to the DOE Under Secretaries of Energy, Science, and Nuclear Security, with other supporting offices like ARPA-E, the Loan Programs Office, and IA reporting to the Deputy Secretary. Additionally, OSPP chairs the previously described CMMCG. The CMMCG reports to, and supports, an Assistant Secretary-Level coordinating council referred to as the Critical Minerals and Materials Council, chaired by the Assistant Secretary of Fossil Energy. The CMMCG was founded based upon a recommendation made in early 2020 by DOE's Research Technology Investment Council's Critical Minerals Working Group. It provides recommendations to the Deputy Secretary and Under Secretaries, and will guide the implementation of this strategy over the coming decade.

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Goals and Objectives

A series of programmatic objectives under each of the four DOE strategic goals are described in more detail here, highlighting the unique contributions that DOE can offer to support the mission requirements and develop a secure and resilient domestic critical mineral supply chain.

1. Drive scientific innovation and develop technologies that will ensure resilient and secure critical mineral and material supply chains independent of resources and processing from foreign adversaries.

Addressing the challenge of critical minerals and materials requires significant efforts across the DOE complex, ranging from fundamental science through use-inspired and applied research, to application R&D in close collaboration with industry. For more than a decade, the United States has invested in science and technology to reduce the Nation's growing dependence on foreign sources of critical minerals and materials and foreign manufacturing supply chains. Throughout this period, the DOE R&D complex has targeted three pillars designed to mitigate potential economic and strategic supply chain disruptions: Diversifying Supply, Developing Substitutes, and Improving Reuse and Recycling. Moving forward, DOE will continue to balance efforts across these three pillars.

While these investments have led to considerable progress, the United States needs a more connected and coordinated research and development strategy to facilitate an evolution to United States critical mineral and material *independence*. The interplay of critical minerals and materials with global leadership, energy dominance, economic growth, and strength in national defense commands an improved strategic approach for DOE and the interagency.

Generating mechanisms for increased communication and cooperation between programs and offices, and with other agencies, will facilitate and increase innovation from both existing work and future efforts. An R&D strategy shaped by departmental coordination and public-private partnerships enables the United States to more efficiently address the underlying scientific and early-stage applied research challenges, and facilitates the validation and verification of new materials and processes in key technical areas across critical mineral and material supply chains of critical minerals and materials. Finally, DOE can leverage the R&D strategy to establish partnerships with allied countries that address gaps in our domestic critical supply chain.

Objective 1.1: Coordinate on-going R&D activities and capabilities;

Many technologies supported by DOE and other federal agencies share similar vulnerabilities due to their dependence on critical supply chains. Current research investments aimed at mitigating these vulnerabilities (see DOE current activities) present an opportunity for more expansive, crosscutting activities built upon increased coordination and communication. To realize the promise of crosscutting critical research, organizational actions/initiatives are needed to connect the entire critical minerals and materials research community across the DOE complex and interagency. Creating integrated program meetings, coordinating funding opportunity announcements, and conducting interagency high-priority workshops will improve research communication and collaboration across all program offices. The NSTC Critical Materials Subcommittee produced a cross-agency survey which will be utilized to identify opportunities to optimize RD&D activities across agencies. Regularly scheduled interagency workshops and integrated program meetings will connect researchers with similar interests and stimulate collaboration. DOE program offices (EERE, SC, FE, ARPA-E) can leverage prior investments via follow-on funds in Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR) and Technology Commercialization Fund programs to address a broader section of the critical minerals and materials research space. The DOE complex will consider standing-up an enduring collaboration mechanism to address a broad spectrum of supply chain challenges, following the example of the National Virtual Biotechnology Laboratory (NVBL). This forum would dovetail and connect end-to-end supply chain research efforts and could incorporate both academia and industry partners.

SC and NE operate user facilities at DOE National Laboratories that provide leading-edge capabilities for

basic and applied R&D that are not typically available in academia or industry. These include x-ray and neutron probes, irradiation and post-irradiation examination capabilities, nanoscale science centers, and high-performance computing. In addition, many DOE National Laboratories have test and demonstration facilities that could be leveraged to support the development and scale-up of advanced technologies that are less susceptible to mineral and material criticality.

Objective 1.2: Develop coordinated R&D roadmap;

To provide long-term focus to the more well-coordinated DOE R&D efforts in critical minerals and materials, DOE will develop a R&D roadmap that guides the collective capacity of academia and the National Labs in partnership with the private sector. The roadmap will address the underlying scientific and early-stage applied research challenges, identify R&D investment gaps should they exist, enable new materials and processes, and include an end-to-end analysis of supply chain dependencies. Furthermore, the roadmap will employ the Department's unique capabilities that support crosscutting geological science, resource mapping, fundamental materials and chemical science, advanced scientific and computational user facilities, manufacturing, and environmental health and safety. Making the roadmap open for public comment will capture feedback and insight from stakeholders.

To enable a coordinated R&D roadmap, program offices will examine investment mechanisms and coordinate funding announcements that support the overarching departmental strategy, while encouraging researchers to work together. To illustrate this concept, DOE has recently engaged in the development of next generation materials and systems to reduce reliance on critical materials for energy and security needs: The Wind Energy Technologies Office (WETO) is funding R&D on an advanced, lightweight drivetrain that has little to no rare earth elements and the Vehicle Technologies Office (VTO) is developing traction motors that eliminate heavy REEs or use alternatives to permanent magnet motors altogether. DOE will increase coordination between programs and those funded by FE to extract and process the critical minerals and materials that will be needed by the WETO and VTO program technologies. Then, the coordinated programs will provide support for the private sector to demonstrate, evaluate, test, and qualify these new materials for civilian and defense applications.

In the development and execution of R&D investments, DOE will balance its mineral and material focus based on criticality, risk, and supply chain analysis—including those supply chains where federal investment will have a significant impact. Assessments discussed under Strategic Goal 3 will inform criticality and risk while engagement with industry discussed under Strategic Goal 2 will identify the most market-viable opportunities for investment. In these assessments, DOE will develop specific mitigation strategies to address prioritized materials issues. For example, the United States does not have sufficient domestic resources to meet expected demand for certain critical materials, such as cobalt and gallium. Such materials require developing substitutes, improving the efficiency of critical material use, extending the product life to reduce demand, improving reuse and recycling, or partnering with foreign allies to secure supply chains.

Objective 1.3: Identify future R&D opportunities through public-private partnerships;

In addition to its current R&D portfolio, DOE can shape future critical minerals and materials investments through public-private partnerships that focus on pilot scale facilities for mining, extraction, and processing. Stakeholders will be provided the opportunity to participate in technical and economic feasibility studies, such as those on the production of critical minerals and related manufactured materials from secondary and unconventional sources (including coal-based resources, mine tailings, smelter slag, waste streams, end-of-life products, and seawater deposits) as outlined in Federal Strategy 1.3.[30] Stakeholders will also inform DOE's future R&D focus for developing new substitute materials and systems, as well as opportunities for improving reuse and recycling. R&D to improve the efficiency of separations of critical minerals and materials is needed for all phases of critical minerals and material supply chains, with research spanning early-stage discovery to piloting. Fundamental research into rare earth f-electron chemistry and physics will impact functionality and opportunities for replacement, reduction, and separation.

As one example, the CMI is in its eighth year of its 10-year charter. There is an opportunity to extend and expand its charter to address other parts of the supply chain, additional materials, and higher technology

[30]*Call to Action 1.3 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

readiness levels (TRLs). For example, a CMI follow-on consortium could span from discovery to deployment of technologies that diversify supply, develop substitutes, drive reuse, recycle, and more efficient use of critical materials. The consortium could include the de-risking and scale-up of innovative technologies from the lab to pilot-scale (TRL 5-7) in order to establish globally cost-competitive domestic capabilities. Such capabilities may be targeted on gaps in supply chains such as metal conversion, magnet manufacturing, and more efficient use (e.g., reuse and recycling). The scope of the consortium's research would also reflect the breadth of efforts across the Applied Energy Offices and the Office of Science. The specific projects awarded would complement work of each office's mission-specific critical minerals and materials programs, maximizing cross-program coordination through information sharing, while ensuring non-duplication of efforts. Test-bed facilities could be included in order to scale up technology solutions around identified gaps such as metal conversion or magnet manufacturing.[31]

The consortium's portfolio of early-stage projects could be aligned with emerging critical materials needs for the Nation based on up-to-date criticality and resource assessments (see Strategic Goal 3). This public-private partnership would contribute to a critical innovation ecosystem that transitions DOE-supported technologies and practices into U.S. capabilities, and bridges the gap that often exists between research and development and commercial production.

Objective 1.4: Identify potential collaboration opportunities in R&D with interagency and international partners;

A significant volume of materials is needed to support future energy needs. As noted above, the United States does not have sufficient domestic resources to meet these needs alone for certain critical minerals and materials, such as cobalt and gallium. The United States cooperates with allies and partners around the globe on issues related to critical minerals and materials. DOE has led cooperative discussions with the European Union and Japan on the trilateral R&D critical materials group and is engaged with Canada and Australia on bilateral critical minerals action plans (see Strategic Goal 4).

These partnerships have shared strategy and information on each of the country's efforts in critical materials research. This has led to collaborative research efforts focused on specific aspects of critical materials; for example, developing substitutes for rare earth permanent magnets.

It is important to continue and expand collaborative research and development with interested partners to address gaps in the U.S. critical material supply chain, especially on minerals and materials the United States cannot source domestically. International exchanges of information on best practices for addressing critical mineral issues would improve the ability of the United States to secure access to these minerals. Coordination among DOE researchers is needed to ensure that program offices develop complementary capabilities with international allies and interagency partners to prevent saturation of raw and refined materials, including processing and manufacturing capabilities on the global market, and IA identifying opportunities and risks in facilitating outreach to existing and new international partners. Research collaborations can be leveraged to drive down costs and supply disruptions for both the United States and its allies by sharing S&T discoveries to support the development of these complementary capabilities.

Interagency coordination is vital to strengthening ongoing investments and establishing new strategies that support critical minerals and material research. The DOE will leverage its research and development framework and its Loan Programs Office to facilitate interagency collaborations with:

- Department of Defense (DoD) to utilize investment made through DPA Title III, and to expanded partnerships between programs like the Defense Logistics Agency (National Defense Stockpile), Defense Threat Reduction Agency (DTRA), and Defense Advanced Research Projects Agency (DARPA);
- DOI, USDA, and EPA to understand the environmental impact of technologies used in critical materials;
- EPA to collaborate on circularity and recycling;
- USGS for resource availability and economic geology;
- NASA and others for remote sensing and resource analysis;
- NSF and DOE's Office of Economic Development and Diversity for academic and work force development actions;

[31] *For example, DOE's ReCell Center can expand private industry access to its pilot testbed to support materials recycling process development and scale-up.*

• Export-Import Bank and Development Finance Corporation for funding and financing projects;

• DOC for trade and market issues;

• Department of State (DoS) for international engagement; and

• NSTC to convene all federally funded consortia engaged with critical minerals and materials to better understand their capabilities.

These potential partnerships are discussed in objectives 3 and 4 below.

2. Catalyze and support private sector adoption and capacity for sustainable domestic critical mineral and material supply chains.

A key challenge in developing sustainable domestic critical supply chains is successfully transitioning innovative technologies from lab to adoption and deployment by industry. A common thread running through most of the 35 critical minerals is incomplete and, in some cases, absent supply chains from extraction, beneficiation, separation, purification, and manufacturing, including reuse and recycling. Many processes used currently in foreign supply chains are also unsustainable—especially in terms of harmful environmental impact. There are several fundamental factors that combine to make this exceptionally challenging.

For most critical minerals and materials, there is also limited domestic industry willing to adopt technologies. Original Equipment Manufacturers (OEMs) don't have capacity or capability to address a multitude of supply chains or balance trade-offs. For example, a smart phone contains approximately 70 of the 83 non-radioactive elements.[32] It is nearly impossible for a single company to enable secure supply chains on their own. Development and adoption of recycling technologies in industry is challenging due to a lack of reliable end-of-life product streams, and a volatile market in which domestic recycled materials would compete with imported virgin materials. There are several factors to address:

1. How to provide a clear path for adoption of technologies while providing production capability for mission critical materials and how to prioritize and address supply chain gaps?

2. There is typically limited private-sector investment in the critical materials area—typically the result of concern over market opaqueness and challenge factor 1 above.

3. There are very few testbed or pilot-scale facilities to help validate, demonstrate, and compare new technologies for a wide-range of feedstock inputs.

4. Getting industry input is often a challenge for researchers at DOE National Laboratories and in academia at early stages of discovery and development, and completing the hand-off of new technologies is difficult without sustained engagement between industry, academia, and National Laboratories to address scientific and technical challenges during scale-up.

DOE is considering how it can overcome these challenges and providee a clear path for the adopting of technologies while providing production capability for mission critical minerals and materials. DOE will investigate mechanisms for the government to work with industry to ensure economic viability and cost effectiveness when domestic technology is developed at scale for commercial use. Finally, DOE will identify critical supply chain chokepoints and how they can be safeguarded against disruption.

While R&D investment is important, it is not sufficient to address the challenges alone. DOE will renew sustained efforts to directly engage industry throughout the development cycle to maximize the impact of its investments.

DOE will look to utilize, to the fullest extent possible, its authorities to increase U.S. private industry investment in innovation and improve technology transition and transfer from federally funded science and technology. DOE can connect with DoD to discuss the potential of leveraging existing DoD programs to incentivize private sector investment in critical mineral extraction, processing, and manufacturing R&D and commercialization—such as the significant investments in the DPA Title III program.[33]

Objective 2.1: Coordinate on-going technology transition and transfer activities and capabilities;

[32]*Smartphone: Smart Chemistry, American Chemical Society, 2015, https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2014-2015/smartphones.html*

Within DOE, there are significant on-going activities to develop technologies to address supply chain challenges. These activities were highlighted above and in Goal 1. Recently, the Department has greatly increased the emphasis on partnering with industry to co-fund pilot-scale and demonstration facilities—especially in the area of separation, processing, extractive metallurgy, and reduction of critical minerals to metals and alloying. In addition, the Department funds technology transfer activities, building from the fundamental and applied research investments towards commercialization. Moving forward, DOE will pursue coordinated opportunities to build an innovation pipeline, from fundamental research through applied technology to commercialization and deployment.

There are several models for public private partnerships. One model could be CMI, which has played a leadership role in engaging with the private sector and partnering with other laboratories outside of the consortium that have relevant capabilities. CMI is poised to greatly expand engagements with additional laboratories, universities, industry, and with programs like the Lab Embedded Entrepreneurship Program and SBIR. National Laboratory researchers in partnership with academia and industry could provide impartial technical analysis of new technologies developed across the materials ecosystems and develop standards for comparison for energy efficiency, environmental impact, and broader techno-economic analysis. These resources could guide investment into promising technologies and help overcome the valley of death between basic and applied research and the subsequent adoption by the private sector.

Other models include the regional innovation centers under development through the CORE-CM Initiative. This partnership structure has proven very successful in other programs, such as the Regional Carbon Sequestration Partnerships. The CORE-CM projects will bring together all research being conducted within a basinal region throughout the entire supply chain, linking resource developers with end-users.

There are a number of highly specialized facilities across the complex which can address specific challenges across the entire supply chain. These include Ames Laboratory's Materials Preparation Center, which is the only DOE facility converting rare earth oxides into high purity metals in addition to its expertise in novel synthesis and purification of metals. The recently commissioned Controlled Atmosphere Magnet Processing System at Ames Lab is developing magnet processing capabilities with the potential to transfer to industry.

The National Energy Technology Laboratory (NETL) has facilities for materials development and validation. These are currently leveraged within the eXtremeMAT program, and opportunities exist to initiate larger scale alloy production with equipment which is currently underutilized. NETL has also developed an assessment method and tool to systematically predict and assess domestic deposits of REEs from carbon ore and other sedimentary systems using a big-data, machine learning-enabled geoscience approach to improve prediction and identification of high concentration deposits of REEs and critical minerals (CMs) in sedimentary, carbon-ore based, systems. In 2020, NETL has begun expanding the REE-SED assessment approach to support its application to the development of an assessment method for predicting CMs from mine byproducts and waste streams.

ANL has research and development capabilities and user facilities, such as the Advanced Photon Source, that offer state-of-the-art measurement, characterization, and analysis of materials and chemical processes. Together with the Advanced Leadership Computing Facility, these user facilities can drive rapid materials discovery and synthesis research, including heavy element chemistry, separations, and autonomous systems for ore identification and mining. ANL's Materials Engineering Research Facility has extensive capabilities for critical material separation and purification process development and scale-up from bench to pilot scale, enabling robust feasibility and techno-economic evaluation, as well as current research on urban mining of critical materials. DOE's ReCell Center, co-located at ANL, also has specialty capabilities in battery recycling process development and scale-up focusing on Lithium-ion chemistries.

The new Energy Sciences Capability building at Pacific Northwest National Laboratory (PNNL) aims for industrial engagement in use-inspired fundamental chemical and materials sciences. Savannah River National Laboratory (SRNL) has extensive laboratory capabilities to help conduct bench and pilot testing, including chemical separations, chemical analysis, flow sheet development, and process optimization.

Idaho National Laboratory (INL) possesses a variety of laboratory and pilot-scale equipment capabilities

[33]*Call to Action 1.5 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

and expertise that support research and development activities for the separation and purification of critical materials. INL has a wide range of separations equipment specific to solvent extraction operations (e.g., mixer-settlers, pulsed columns, and centrifugal contactors) and the expertise to develop and test multi-stage, counter-current engineering flowsheets. The INL's Biomass Feedstock National User Facility and associated infrastructure and capabilities for characterizing, sorting, and pre-processing of materials were developed with the goal of promoting industry engagement and partnerships. These facilities will allow testing of processes to recover value from waste streams, such as municipal solid wastes or electronic wastes that could prove to be significant domestic sources of rare earth elements and other critical materials.

The Oak Ridge National Laboratory (ORNL) has a variety of laboratories and equipment for research and development in the separations, purifications, recycling and reuse of critical materials, and the handling of radioactive byproducts. ORNL's Manufacturing Demonstration Facility is diversifying into functional materials AM that could more efficiently use critical materials such as in printing rare earth magnets. The Battery R&D Manufacturing Facility has the capability to evaluate and validate the properties and performance of the recycled materials and has experience working with the private sector on industrial decisions.

Introducing a mechanism for information exchange between labs and university/industry research will enhance collaboration and broaden the impact of DOE investments. DOE will mobilize a summit that facilitates a two-way exchange of information and ideas among industry, universities, manufacturers, investors, and end-use customers with innovators and experts from across the National Labs and broader DOE R&D complex. This group will be positioned to align capabilities with industry needs and catalyze market pull for tech transfer through public-private partnerships. OTT designed a similar mechanism, InnovationXLab, which can be used as a model for this initiative.

As discussed above, the National Laboratories have extensive facilities that could be used to tackle key critical supply chain challenges. One possibility to utilize these extensive facilities more efficiently would be to create incentives through a small business voucher program for accessing the National Laboratories in which industry takes on some cost, but a considerable amount is funded by DOE. Given the current market conditions, there is little incentive for the private sector to conduct research in this area.

Objective 2.2: Develop future opportunities for improved adoption and capacity;

As discussed in Goal 1, DOE partnering with the National Laboratories, academia, and industry will continue to be a key strategy in addressing the R&D challenges associated with supply chains. A significant challenge is having the private sector adopt new technologies to develop new domestic capacity. A successful model to catalyze this adoption and capacity are public-private partnerships, which can successfully accelerate the R&D and technology deployment by de-risking and scaling innovations. Structured correctly, such partnerships can also enable technology transfer for industrial adoption and capacity building. There are many models within DOE and the Federal Government for successful partnerships with industry, including the Energy Innovation Hubs (e.g., CMI), Manufacturing USA Institutes (funded by DOE, DOD, and National Institute of Standards and Technology [NIST])[34], and the Manufacturing Extension Partnership (funded by NIST)[35]. Similarly, the Fraunhofer Institutes[36] are a highly touted model widely used in Europe. Moving forward, DOE will explore a large-scale pubic-private partnership (PPP). There is a clear need for DOE engagement with industry to enable validation and demonstration of key supply chain steps for critical minerals and materials. Through assessing the need and validity of such a partnership, DOE will look to engage a wide range of stakeholders throughout the supply chain and leverage interagency interest. The goal of the partnership would be to diversify supply chains, develop alternatives, and improve reuse and recycling—while catalyzing the adoption of sustainable mining and processes, directly supporting the Federal Strategy recommendations 1.2 and 1.4.[37]

For example, DOE will explore development of a manufacturing public-private partnership that would facilitate vertical integration and be retained

[34]*Manufacturing USA, https://www.manufacturingusa.com/*

[35]*Manufacturing Extension Partnership (MEP), National Institute of Standards and Technology, U.S. Department of Commerce, https://www.nist.gov/mep*

[36]*Fraunhofer Institutes, https://www.fraunhofer.de/en/institutes.html*

[37]*Calls to Action 1.2 and 1.4 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

by the manufacturing end-users. These end-users should include multiple companies (e.g., magnets, components, batteries, motors, etc.). The partnership would include the entire supply chain, from resources to extractive metallurgy, with a focus on metal production.

As discussed in the Federal Strategy, DOE will also look to provide support for small and medium business on critical mineral issues[38] by leveraging and expanding existing coordination between DOE's CMI and CORE-CM, NIST's Manufacturing Extension Partnership, relevant Manufacturing USA institutes, National Laboratories, and universities.

Partnerships with industry could enable new extraction technologies to be tested under field conditions at a larger scale than can be achieved in the laboratory; for example, field testing of treatment and element extraction from geothermal fluids, produced water (from oil, gas, carbon storage operations), or separation and reduction processes at existing pilot facilities. As noted, there exists a need for intermediate-scale test facilities for exploring scale-up and operability of novel concepts and to promote public-private collaborations.

Materials certification is another challenge for industry. There are long lead times to bring new materials to market. In other DOE programs, approaches to certification and uncertainty quantification analysis have been developed to help direct the steps needed to get a new material to market. This could be part of an expanded techno-economic analysis where the materials certification barriers are identified, and DOE helps meet certification.

Objective 2.3: Engage and support key stakeholders;

Working with key stakeholders is essential in pursuing sustainable domestic critical supply chains. DOE will look to continue to engage stakeholders to identify future opportunities, expand efforts, and address key issues; send signals to industry; and provide security and frame the duration of government investment, policy, long-term liability, budget/appropriations, and metrics. As part of the Federal Strategy, DOE is committed to establishing (on behalf of the Federal Government) a National Critical Minerals and Supply Chains Advisory Committee to seek advice on the metal and non-metallic sectors of U.S. industry producers and primary processors.[39]

DOE has recently taken a leadership role in supporting establishing industrial standards, including sustainability standards that address environmental and social impacts. The United States is engaged with multiple technical committees through the International Standards Organization (ISO) on lithium and REEs. These standards also represent significant coordination with international allies, as discussed under Strategic Goal 4. In addition to ISO efforts, DOE will strengthen its evaluation of other countries' approaches to private industry supply chain issues.

In 2020, many manufacturing supply chains were disrupted as a result of the COVID-19 pandemic. This highlighted the need to reshape approaches and priorities for robust, resilient, and secure supply chains, including the need for improved data for many materials - including critical materials. DOE will look to gather information on mitigating disruptions through applying technologies related to Industry 4.0, which describes the ongoing automation of manufacturing and industrial practices using data-enabled/smart technology.[40]

DOE will work with stakeholders to identify key needs and challenges related to implementing sustainable innovations in all stages of the critical minerals supply chain, including: resource characterization of all resources in onshore and offshore environments; developing transformational conventional mining and novel mining approaches in both onshore (in-situ mining) and offshore mining; second-generation and transformational critical beneficiation, extractive metallurgy, reduction and alloying; downstream processing, associated manufacturing, and improved U.S. industrial base resilience; improving national recycling and materials recovery infrastructure; identifying uses of secondary and unconventional sources of critical minerals; improving product designs that facilitate critical mineral recovery; and exploring technological/R&D needs to facilitate material recovery.[41]

[38]*Call to Action 1.6 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

[39]*Call to Action 2.2 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

[40]*The Fourth Industrial Revolution: what it means, how to respond. World Economic Forum. February 2016: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/*

There are key barriers that limit collaborations even when DOE National Laboratories and industry partners would like to partner to address key critical challenges. In some cases, there are concerns over existing and co-developed intellectual property and legal hurdles needed to establish agreements. There are also cultural differences. In particular, metrics for success differ greatly between National Laboratories and Industry. However, lack of awareness of the capabilities and expertise of the National Laboratories and how to tap these resources may be one of the largest challenges.

For example, mineral extraction and processing companies are not generally familiar with National Laboratories expertise and vice versa. There is also a mismatch between scientific expertise and high TRL infrastructure in some key areas. For example, expertise in chemical separations of heavy elements resides at DOE Laboratories that do not have scale-up or demonstration facilities useful for industrial R&D. Partnerships to overcome such barriers will significantly expand the impact that the Laboratories can have to develop a secure and resilient domestic supply chain.

Examples include NE's Advanced Reactor Demonstration Program (ARDP) for accelerating U.S. nuclear technology development, demonstration, and deployment, and DOE Energy Innovation Hubs, including the Joint Center for Energy Storage Research and Grid Storage Launchpad, to leapfrog current battery technology. DOE will further disseminate the expertise and capabilities at National Laboratories in the area of critical minerals and materials. DOE will also continue to engage the private sector on how it can appropriately support, engage, and understand the potential economic impacts of success of the Laboratories' work and the DOE investment.

Funding is often difficult to obtain for mid-TRL (4-6) projects that focus on transition of technologies from early- to later-stage research. DOE has implemented a number of promising programs to transfer advances to industry, such as the Technology Commercialization Fund program. With materials moving through the TRLs, a market-viable solution often takes longer than the funding arc of a typical R&D program. Enabling a longer-term relationship with partners who are showing progress is essential to translating these scientific advances into viable solutions for industry.

Finally, the engagement of the American public as a stakeholder is important to ensure the success of addressing critical mineral and material challenges. Existing scientific seminar series could be tailored to the broader public to inform the American people of the research efforts and successes funded by the DOE Complex. Outreach efforts could be designed to engage in conversations with the American public on the importance of these issues and better understand concerns so that they can be addressed at the research stage before nearing transition to market.

Objective 2.4: Enable technology transfer mechanisms;

Policy development serves as an effective tool to enable technology transfer and will be considered to help decrease price volatility and enable domestic operators in the United States to compete in the market.

As discussed in the Federal Strategy, DOE will also coordinate with other government agencies to evaluate the effectiveness of tax incentives for investment in new technologies and government purchase programs based on the use of new technologies using domestic materials in the production of goods purchased.

The Department also has unique authorities to issue loans to facilitate the deployment of innovative technologies. E.O. 13953 directed DOE to develop updated guidance on how authorities for the ATVM and Title XVII programs could be applied to critical mineral and material supply chains. DOE has recently published new guidance and rules to ensure clarity in how DOE's loan programs could be accessed by potential critical minerals and/or materials projects that are in need of private sector financing. Broadly, these government backed loans are intended to support projects that are of a technological risk level that is unsupportable by traditional private sector financing mechanisms but show great promise and meet the requirements of the statute, regulations, and rules governing their use.[42]

[41]*Call to Action 2.3 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

[42]*Notice of Guidance for Potential Applicants Involving Critical Minerals and Related Activity, U.S. Department of Energy, 85 Fed. Reg. 77202, 2020, https://www.federalregister.gov/d/2020-26407*

3. Build the long-term minerals and materials innovation ecosystem—fostering new capabilities to mitigate future critical mineral and material supply chain challenges.

Critical supply chain challenges can take a variety of forms and have diverse impacts on the U.S. economy and national security. The fallout of the COVID-19 pandemic highlighted the critical importance and interdependency of government and industry supply chains, as well as risk associated with U.S. dependence on offshore sourcing for critical minerals and materials, processing, and components. Similarly, the ensuing Fourth Industrial Revolution represents a shift towards digital technologies and data to enable new revenue and value streams.[43] By enabling a network of improved criticality and resource assessments, U.S. critical mineral supply chains can circumvent challenges that arise from the combination of increased critical mineral and material dependence, driven by widespread adoption of emerging technologies, non-market forces like opaque trading markets, and unforeseen future supply chain disruptions.

Equally important is the ability to identify and resolve supply chain disruptions, build platforms for large-scale data analysis and visualization, and develop predictive supply chain tools. Existing supply chain models should be leveraged to examine the availability and sustainability of raw materials, viability of domestic material supply, and impacts of substitutions, trade policies, and disruptions. These advanced analytical tools, including agent-based models, intrinsically capture supply chain dynamics and are particularly adept at evaluating the implications of specific critical mineral and material projects from various sources and new technology adoptions in the context of the broader market. From a material criticality standpoint, these tools can enhance DOE's ongoing efforts to compare the relative supply chain risk and embedded demand of materials in clean energy technologies.

Understanding supply chain issues at the early stages of relevant technology development, collaborating with United States and allies to develop robust supply chains at the outset, and developing material applications with recycling and recovery in mind are essential. This understanding will inform future investments and efforts across the innovation ecosystem, from fundamental science to technology transfer activities. DOE is well-poised to reduce future risks for domestic manufacturers that rely on critical minerals, create a favorable business climate for production facilities at different stages of critical mineral supply chains, and support the economic security and national defense of the United States—all of which will reduce the Nation's vulnerability to critical mineral supply disruptions.

Starting in 2010, DOE performed a series of material criticality assessments based on the two dimensions of supply risk and importance to energy.[44,45] These analyses aimed to identify priority critical materials that merited focused attention based on projections of energy technology demand under various scenarios, given supply risk. The future scenarios looked at expected changes in both global technology deployment and material intensity. The DOE reports, as well as additional analysis supported by the CMI, the National Laboratories, and DOE program offices, address vulnerability and fragility across the supply chain, market dynamics and implications, trade patterns, and intellectual property.

An important component to material criticality assessments involves improving our understanding of domestic critical resources. DOE aims to work with the USGS to improve and publicize mapping data, collection, and analysis, emphasize interagency efforts; and conduct critical mineral resource assessments to support domestic mineral exploration and development.

Finally, if the United States is to grow domestic critical mineral supply chains, there is significant progress to be made in workforce development. The entire domestic critical minerals supply chain faces workforce challenges, including aging and retiring personnel and faculty; a lack of coordinated STEM education investments; insufficient diversity, equity, and inclusion; negative public perceptions about the nature of mining and mineral processing; and foreign competition for talent. As an example, DOE's CORE-CM Initiative is taking targeted steps to address this challenge; however, additional efforts will be required for there to be enough qualified U.S. workers to meet domestic production needs.

[43] *The Fourth Industrial Revolution: what it means, how to respond. World Economic Forum, 2016, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/*

[44] *Critical Materials Strategy, U.S. Department of Energy 2010, https://www.energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf*

[45] *Critical Materials Strategy, U.S. Department of Energy, 2011, https://www.energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf*

Objective 3.1: Develop a robust criticality analysis framework;

It is important to understand the characteristics of resilient supply chains of critical materials for energy technologies under dynamic market conditions, including: neodymium and dysprosium for magnets in clean energy and national security end-use applications; cobalt and lithium for lithium-ion batteries in energy and national security end-use applications; and gallium for semiconductors in LEDs and power electronics for clean energy and national security end-uses applications. DOE will apply this understanding to prioritize investments in R&D and determine where to focus effort to scale up innovation addressing vulnerabilities (to supply/demand mismatch, disruption, and market volatility) at supply chain stages, including mining, separations and processing, manufacturing, and recycling. However, prioritization will also be informed by the identification of the greatest opportunities for market viable supply chains.[46]

DOI, in collaboration with the NSTC Critical Minerals Subcommittee, developed a list of critical minerals[47] that became a focus of the Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals.[48] Since mineral criticality changes over time, the critical minerals list will be updated periodically using a transparent, documented methodology that considers changes to supply, demand, concentration of production, and current policy priorities. It is also important to prioritize and categorize minerals on the list to enable commodity-specific mitigation strategies. DOE will initially identify 3-5 key supply chains that are fragmented, have supply risk, and hold value across multiple office missions. In parallel, efforts will be pursued to document all CM and REE unconventional resources (e.g., end-of-life products, manufacturing scrap, geothermal brines, seawater, tailings, mine drainage, and ash) in collaboration with USGS. In addition to a critical minerals list, the development of a strategic material category would recognize that all materials important to the DOE mission do not have the same supply chain challenges and distinguish between critical and other important materials (e.g., copper). To best organize and utilize these lists, DOE will create a material demand and usage clearing house, as well as focus on improving data sets in relation to availability, timeliness, and completeness.

DOE will also perform retrospective analyses to understand the effectiveness of and learn from federal R&D investment strategy addressing: (1) Diversification of global critical mineral and material production and supply chains; (2) Pursuit of substitutes; and (3) How to reduce, reuse, and recycle critical minerals and materials. This strategy will promote resilience under changing market conditions across various key supply chains over the short- and long-term by drawing on successful analysis methods. Further, best practices will bolster future criticality assessment techniques.

Criticality analysis, both within DOE and in the interagency, will continue to be important. DOE will continue to support the interagency methodology to periodically assess market trends and competitiveness of the U.S. critical mineral and material industry and its downstream supply chains, particularly in energy applications, in order to recommend policies and strategies such as government investment in R&D, capacity expansion, stockpiling, and trade actions. The National Laboratories can inform current criticality assessments by accounting for dynamic market behavior at various stages of individual material supply chains.

When performing critical mineral and material resource assessments, it is important to note that some minerals are geologically coupled with primary products and can only be produced as byproducts. Since byproduct minerals are typically produced in low volumes and have low economic value compared to the main resource being mined, the byproduct can be heavily dependent on the profitability of the main resource. For example, gallium, a critical mineral utilized in many domestic high technology military and civilian applications, is produced commercially as a byproduct of bauxite and zinc ore processing. In accordance with the Federal Strategy,[49] DOE along with DoD, DOI (USGS), and EPA, will identify potential significant secondary and unconventional sources of critical minerals and materials, as well as the technological

[46]*DOE funded ANL to evaluate magnet materials critical to wind turbine and vehicle technologies. This agent-based model was expanded by DoD's Defense Logistics Agency to evaluate material requirements for rare earth stockpiles in the event of disruption (including COVID-19) and conflict scenarios, which are included in their bi-annual Strategic and Critical Material Stockpile Report to Congress.*

[47]*Draft Critical Mineral List—Summary of Methodology and Background Information—U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359, U.S. Geological Survey, U.S. Department of the Interior, 2018, https://pubs.usgs.gov/of/2018/1021/ofr20181021.pdf*

[48]*Call to Action 1.5 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

[49]*Call to Action 1 of A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, U.S. Department of Commerce, 2019, https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals*

developments needed to improve domestic recovery capability, and provide a periodic status update to the CMS. This endeavor can be accelerated by leveraging the Department's RD&D for next generation materials through Strategic Goal 1.

Resource assessment can be advanced through the implementation of resource extraction and characterization technologies. Novel recovery systems, advanced materials and sensors for real-time operations, advanced controls, and AI to support recovery in harsh environments, and extraction standards are key components of an integrated extraction approach.

DOE is well-positioned to transform linear supply chains to fully realize opportunities for circularity and efficiency. Focus will be placed on connecting supply chains and fostering collaboration with industry and municipal waste to integrate recycling and reuse strategies into supply chains. Leveraging RD&D programs for next generation materials and processes from Strategic Goal 1 will enable DOE to optimize the value of recycling streams. DOE can lead by example by using DOE data centers to pilot technology to recover REEs from hard disk drives. Similarly, DOE has the platform to connect National Laboratories and industries to characterize and establish grades of recycled critical materials that would broaden the potential for reinsertion into the supply chain.

Objective 3.2: Improve and enable mapping of critical mineral and material deposits;

The lack of geophysical, geological, topographical, and bathymetrical mapping at the scale required for mineral resource assessments and private sector exploration is a critical information gap that must be closed to facilitate domestic development of critical resources. USGS data has shown that less than 18 percent of the United States land mass has been geologically mapped at the necessary scale, and less than five percent of the Nation has regional aeromagnetic datasets at the required resolution to perform robust mineral resource assessments. Similarly, less than 35 percent of the Nation's Exclusive Economic Zone has been bathymetrically mapped with modern methods, and even less has been geologically mapped or characterized with enough resolution to facilitate mineral assessments.[50]

DoD, EPA, FEMA, DOI, DOC, DoS, USDA, and DOE are all stakeholders in mapping data and analysis. Federal agencies will develop and use a protocol that promotes discoverability, accessibility, and usability of existing and future data. Several DOE program offices and National Laboratories are already involved with collaborative projects with USGS research efforts to develop enhanced mapping technology. USGS is improving the discoverability of useful datasets by hosting a portal that contains a wide spectrum of minerals-related information and data including geological, geochemical, and geophysical databases; mineral assessments; ore deposit models; and more.[51] GTO is collaborating with the USGS in the Geo-DAWN and Earth MRI projects to better understand the fundamental geologic framework of areas across the Nation with potential for hosting critical mineral and material resources.[52] DOE has significant expertise in sensing and measurement technologies, as well as data analysis for large data sets. DOE will expand upon its current collaboration on projects to to develop and apply remote sensing technologies for landscape, mineral, groundwater, and vegetation analysis, and use machine learning (ML) methods to identify hotspots.[53] NETL will evaluate and model resources. Further, DOE will expand its partnerships with USGS and DoD on such relevant work to ensure DOE technologies and expertise are fully leveraged throughout the interagency.

Application of DOE efforts in artificial intelligence and machine learning (AI/ML) and other data analytics would enhance identification, mapping, and geochemically/mineralogically characterization of critical mineral potential from conventional, secondary, and unconventional sources within the United States. NETL initiated this type of work, developing the REE/CM-SED assessment method and tool to systematically predict and assess domestic deposits of REEs from carbon ore and other sedimentary systems. This method uses a big-data, machine learning enabled geoscience approach to improve prediction and identification of high concentration deposits of REEs and CMs in sedimentary, carbon-ore based, systems. In 2020, NETL began expanding the REE-SED

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

[51] *Mineral Resources Online Spatial Data, U.S. Geological Survey, 2019, https://mrdata.usgs.gov*

[52] *USGS and EERE: Collaborating to Strengthen America's Energy and Resource Independence, 2020, https://www.energy.gov/eere/articles/usgs-and-eere-collaborating-strengthen-america-s-energy-and-resource-independence*

[53] *Open Watershed Science By Design: Leveraging Distributed Research Networks to Understand Watershed Systems 2019, https://doesbr.org/openwatersheds/Open_Watersheds_Low_Res.pdf*

assessment approach to support its application to the development of an assessment method for predicting CMs from mine byproducts and waste streams. Future DOE work in this area could leverage capabilities throughout the complex and couple the REE/CM-SED assessment directly with global models and analysis of materials supply chains across multiple products and sectors, in order to assess risk and identify cost-effective alternative sourcing. These areas promise significant advances to understanding and modeling supply chains. An analogous approach will enable cost-effective recycling and separation processes that may both mitigate supply chain issues and reduce environmental impacts associated with electronic waste and with ore refinement. This would allow these mineral sources to be correlated to design parameters for in-situ or above-ground leach recovery methods, as mineral hosts for critical elements are site-specific and strongly influence cost and feasibility of chemical processes.

Objective 3.3: Grow the American critical mineral and material workforce;

Strengthening DOE's workforce development efforts related to critical minerals and materials requires more investment into interdisciplinary research, and wider communication of the problems and challenges associated with materials criticality. DOE will take active steps to strengthen the U.S. educational program, paying special attention to nurturing early-career STEM participants who will be the backbone of future innovation in critical minerals and materials.

Most university curricula in STEM do not explicitly focus on critical mineral or critical material issues, their link to proposed future applications, or the projected exponential growth in their need as projected by anticipated growth in the deployment of emerging technologies. DOE will consider directing the CMI to create a curriculum for critical minerals and materials on an online course provider. Projects funded through the CORE-CM Initiative can partner with training and workforce development organizations to train the next generation of technicians, skilled workers, and STEM professionals. In addition, DOE can establish a coordinated national plan with academic institutions, including community colleges, technical professional societies, the National Laboratories, research centers, and industrial mining sites to create a comprehensive workforce development infrastructure dedicated to the engineering and STEM disciplines relevant to the identification of deposits, extraction, processing, separation, refining, reprocessing, and recycling of critical materials.

By leveraging existing capabilities and programs within the DOE complex, expanding these capabilities, and coordinating with other federal agencies, DOE can play a central role in training the next generation of scientists and engineers needed to address critical mineral and material challenges. For example, the National Laboratories leverage the DOE Science Undergraduate Laboratory Internships (SULI) program[54] and the NSF Research Experiences for Undergraduates (REU) programs[55] to engage undergraduates in research and establish a pipeline for future graduate students. Similarly, SC extends research opportunities through its Graduate Student Research Program.[56] In addition, externships represent an opportunity for graduate students and postdoctoral associates to better understand industry needs, while forging stronger public-private partnerships.

DOE could also sponsor undergraduate student scholarships or graduate student fellowships in studies relevant to critical minerals or materials. A successful model for this type of support for DOE mission critical student support in an inherently interdisciplinary set of fields can be found in the NE's University Program.[57] Further, the program will be coordinated with workforce development and educational programs of the DOI to maximize the impact and eliminate duplication. DOE could also actively engage in translating the expertise developed from novel methods in the supply chain into communities of practice, such as trade groups, technical schools, and establishment of mining and minerals engineering programs at the U.S. university level.

Establishing synergies and fostering new connections through the minerals and materials innovation ecosystem discussed in Strategic Goal 3 will establish partnerships across the DOE complex with external stakeholders, such as industry, to better understand short and long-term education and workforce needs. This coordination and collaboration will inform efforts to leverage and expand capabilities in the DOE

[54] *Science Undergraduate Laboratory Internships (SULI) Office of Science, U.S. Department of Energy, 2020, https://science.osti.gov/wdts/suli*

[55] *Research Experiences for Undergraduates (REU), National Science Foundation, https://www.nsf.gov/crssprgm/reu/*

[56] *Office of Science Graduate Student Research (SCGSR) Program, Office of Science, U.S. Department of Energy, 2020, https://science.osti.gov/wdts/scgsr*

[57] *Nuclear Energy University Program, Office of Nuclear Energy, U.S. Department of Energy, https://www.energy.gov/ne/nuclear-reactor-technologies/nuclear-energy-university-program*

complex. For example, CMI has developed lesson plans and a toolkit to enable teachers to incorporate critical minerals and materials into their curriculums. These toolkits could serve as a framework and be expanded to reflect the workforce needs of industry. By engaging other Federal agencies, these toolkits could be expanded to address a broader set of S&T topics and all stages of critical mineral and material supply chains. Coordination within the DOE complex could leverage programs, like STEM Rising, to ensure DOE is providing opportunities to all Americans and developing a workforce that reflects the American populace.

Through participation in efforts led by other federal agencies, such as the EPA America Recycles: Innovation Fair or and the upcoming NSF Workshop on Resilient Supply of Critical Minerals, DOE researchers can learn from and connect with stakeholders across sectors to identify partnerships around education and workforce-development.[58,59]

4. Coordinate with international partners and allies and other Federal agencies to diversify global supply chains and ensure the adoption of best practices for sustainable mining and processing.

Global supply chains include diverse constituent phases that each require distinct technical and policy solutions through international cooperation. While DOE has unique expertise and capabilities to address elements of the challenge, to address the entire supply chain, DOE must partner with other Federal agencies and international allies. For many years, DOE has had significant, successful interactions both within the U.S. Government and through international exchanges.

DOE's engagements across multilateral fora and the interagency inform policy, international negotiations, technical innovation, and international standards, all while leveraging the expertise resident to the Department's network of laboratories and industry partnerships. These engagements with partners and allies have revealed shared concerns surrounding the demand growth trajectories for critical minerals and materials, the lack of transparency and resiliency in associated supply chains, and the vulnerability these dynamics pose to international stability and national security. International allies and other agencies are also eager to collaborate with DOE to advance solutions that diversify supply chains, develop markets, stimulate private sector innovation, and establish standards that better support secure and resilient supply chains. A more robust international and interagency engagement strategy is required to coordinate action to meet expected global demand share. Moving forward, DOE will consider ways to expand those partnerships.

Objective 4.1: Increase international exchanges and activate multilateral flora;

DOE's work in international exchanges supports Call to Action 3: Enhance International Trade and Cooperation Related to Critical Minerals under the Federal Strategy. As highlighted above, DOE established a partnership with the European Union and Japan in 2011 through the Critical Materials Trilateral efforts. Through the decade of engagements, annual meetings have enabled information exchanges on innovation and progress on critical mineral and materials. Topics have typically focused on key alternative materials to substitute critical materials, improving the recycling, criticality and supply chain analysis. Australia and Canada have attended recent meetings as observers and will be joining as full participants beginning in 2021. DOE chaired the recent meeting held virtually in November 2020, which focused on recent domestic critical materials policy developments, the future of the trilateral meetings, E.O. 13953, and ISO Standards. DOE will increase collaboration with allies on the issues of critical minerals and materials across various international fora—ranging from the G20 to the International Organization for Standardization. The International Energy Agency's forthcoming Critical Minerals Special World Energy Outlook Report offers an opportunity to begin institutionalization of critical minerals issues into the IEA's structure. Incorporation into its routine publications and market outlooks will help illuminate vulnerabilities in the supply chain, increase accessibility to critical mineral resiliency amongst U.S. partners, and promote development of expertise. DOE will also raise CMMCG in other bilateral dialogues with partners at embassies and other counterparts to address discrete opportunities within the critical minerals and materials value chain.

The U.S.-Canada Joint Action Plan on Critical Minerals Collaboration signed in early 2020 has the potential to be highly productive in view of the vast mineral resources of Canada, its historical strengths in mining and metallurgy, and the common interests between these nations. National Research Council Canada (NRC) has funded a research program that partners

[58]*America Recycles, U.S. Environmental Protection Agency, https://www.epa.gov/americarecycles*

[59]*National Workshop: Resilient Supply of Critical Minerals, National Science Foundation & Missouri S&T, 2020, https://www.criticalminerals.mst.edu/*

with industry in a manner similar to that undertaken by DOE. Strong international agreements between allies—such as the agreement with Canada—can provide a foundation wherein DOE Programs and Laboratories can develop meaningful industry partnerships, many of which have a global footprint.

As mentioned above, DOE also participates in a bilateral partnership with Australia.[60] Led by the Department of State, the U.S.-Australia Critical Minerals Working Group is another path for the Federal Government to coordinate and collaborate with an ally to address global supply chain challenges. Australia's Commonwealth Scientific and Industrial Research Organisation is developing a "roadmap" for critical mineral and material R&D and is pursuing opportunities to incorporate cooperation with DOE National Laboratories in their plans.

CMI actively maintains a bi-lateral relationship with Japan through a Memorandum of Understanding between Ames Laboratory and the Japanese research organization New Energy and Industrial Technology Development (NEDO). Bilateral meetings are held annually and focus on permanent magnets discovery, recycling, and criticality assessments. Information exchanged is subject to export control and intellectual property (IP) protection.

There are additional opportunities to increase targeted international exchanges. Several international research organizations share a common purpose with DOE in achieving sustainable and resilient supply chains of critical minerals and materials. Such organizations include the Rare Earth Industry Association (REIA), Prometia, U.K. Security of Mineral Resources (Sos MinErals), and Natural Resources Canada (NRCanada). However, coordination of research is not currently occurring. Occasionally, U.S. researchers are invited to participate in projects from other countries or regions, for example partnering in the EU Horizon 2020 programs, but generally these are restricted to sharing of publicly available information at conferences and other research meetings. Funding formal research relationships with foreign entities has proven difficult, however, due to the issues related to IP and U.S. Competitiveness clauses of Strategic Partnership Agreements. DOE will strategically coordinate a broader agreement to foster collaborations between U.S. researchers across the National Laboratory complex and international colleagues.

Individual National Laboratories continue to develop international partnerships where the scope of their programs will be enhanced through foreign research institutions or industry. For example, NETL has engaged with Canadian and Australian stakeholders and producers, and is also actively working to be more engaged with South American stakeholders.

Objective 4.2: Coordinate across the interagency;

The formalized mechanism for coordination across the interagency is through DOE's role in the NSTC Critical Mineral Subcommittee (discussed above). DoD has a significant interest in critical minerals and materials as evidenced by Defense Production Act Title III efforts.[61]

Other agencies relevant to critical mineral and material supply chains include: DOI, USDA, and EPA for permitting and understanding the environmental impact of current technologies used in critical minerals and materials; USGS for resource availability and economic geology; NASA and others for remote sensing and resource analysis; NSF and the Department of Education for collaborations with academia and industry to explore new concepts and workforce development; DOC for trade and market issues (e.g., expanding support to innovators); and the DoS for international engagement. Notably, DOE has supported the launch of DoS's Energy Resource Governance Initiative (ERGI), which promotes sound mining sector governance and supports the resilience of energy-related mineral supply chains. Sound governance and responsible sourcing supports leading industry practices that encourages investment and reduces the risks of supply disruptions.

DOE and EPA have an opportunity to collaborate on circularity and recycling (as discussed in Strategic Goal 3). Recently, EERE has provided input on the draft National Recycling Strategy and EPA has engaged with EERE on the Battery Recycling Prize.[62,63] Currently, EPA does not have technology development activity and a broader framework for Re-X (recycling, remanufacturing, reuse) as opposed to just recycling. DOE will coordinate

[60] *United States and Australia Make Progress on Improving Critical Mineral Security, U.S. Department of State, 2020, https://www.state.gov/united-states-and-australia-make-progress-on-improving-critical-mineral-security/*

[61] *Defense Production Act (DPA), Title III Overview, Office of Industrial Policy, U. S. Department of Defense, 2020, https://www.businessdefense.gov/DPA-Title-III/Overview/*

[62] *Draft National Recycling Strategy and Executive Summary, America Recycles, U.S. Environmental Protection Agency, 2020, https://www.epa.gov/americarecycles/draft-national-recycling-strategy-and-executive-summary*

[63] *Lithium-Ion Battery Recycling Prize, American Made Challenges, U.S. Department of Energy, https://americanmadechallenges.org/batteryrecycling/*

with EPA to ensure policy and incentives developed are complementary to recycling and Re-X technology development. DOE worked collaboratively with the other federal agencies in the development and on-going execution of the Federal Strategy developed in response to E.O. 13817. Many of the deliverables contained with the Strategy require extensive cross-agency collaboration. DOE leads the efforts on Call to Action 1: Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains with the Department of Defense as a co-lead. DOE also co-leads Call to Action 2: Strengthen America's Critical Mineral Supply Chains and Defense Industrial Base with DoD serving as the other co-lead role.

In support of Call to Action 1 of the Federal Strategy, NSTC Critical Minerals Subcommittee plans to convene all federally funded consortia engaged with critical minerals and materials to better understand their capabilities. This working group will enlist stakeholder input to match up consortia capabilities with industry gaps and needs.

Beyond the NSTC subcommittee, DOE and the National Laboratories work directly with other federal agencies through existing mechanisms and agreements. Often, cross-agency interactions take the form of collaborative efforts through MOUs between the agencies through the sharing of information and data without exchanging funding. Partnering typically takes place via joint funding proposals when they are available, such as DoD's Strategic Environmental Research and Development Program (SERDP). GTO is collaborating with USGS in the Geo-DAWN and Earth MRI projects to better understand the fundamental geologic framework of areas across the nation with potential for hosting critical mineral and material resource development. DOE and DoD programs discussed in Objective 3.2 leverage the remote sensing capabilities of USGS to better understand the fundamental geologic framework of areas across the Nation with potential for hosting critical mineral and material resources. There may be additional opportunities to explore further partnerships with USGS on data sharing and acquisition—potentially to develop an interagency roadmap with challenges to address.

Several DOE Program Offices and Laboratories are already involved with collaborative projects with USGS research efforts to develop enhanced mapping technology (discussed above). Application of DOE efforts in AI/ML and other data analytics discussed under Objective 3 would allow these mineral sources to be correlated to design parameters for *in-situ* or above-ground leach recovery.

DoD initiated several contracts and agreements with REE producers designed to strengthen the domestic rare earth supply chain. Specific actions include stockpiling, transitioning supply chains to non-Chinese sources, launching engineering studies with the Industrial Base Analysis and Sustainment program (focused on re-establishing domestic heavy rare earth element processing), and partnering with industry to re-establish domestic neodymium iron boron magnet production. DOE will leverage these arrangements to accelerate state-of-the art processing technologies developed by DOE-supported R&D initiatives (as discussed in Strategic Goals 1 and 2). Partnerships with programs of the Department of Defense would inform DOE programs on needs in critical-material supply chains and allow transfer of technology solutions to industry as it responds to defense and national security needs. Expanded partnerships between science programs in the National Laboratories and DoD research organizations will be very beneficial to meet National needs. Coordination with DoD programs including the Defense Logistics Agency (National Defense Stockpile), Defense Threat Reduction Agency (DTRA), and Defense Advanced Research Projects Agency (DARPA) may provide a conduit to transition and scale technology developed in DOE programs. These downstream activities are crucial in identifying end-use applications, which in turn determine direct pathways for extraction, separation, and refining directly into manufacturing processing focused on end-use components and devices. While the defense sector cannot sustain a domestic critical mineral and material supply chain on its own, with commercialization of many innovations is often achieved through high value applications where system performance is the primary driver.

DOE can partner with other Federal agencies, such as the Department of Homeland Security, to promote an enduring collaboration mechanism for supply chain resiliency efforts that convene stakeholders and multi-disciplinary experts to advance end-to-end solutions that balance supply chain risk and efficiency, respond to disruptive trends and technologies, optimize for cost-effective resilience and sustainability, assess the consequences of disruptions to complex interdependent supply chains, and address the challenges of evolving threat and technology landscapes. This approach allows for broad engagement on current and future challenges.

DOE will expand coordination with other federal agencies on issues related to resources and supply chains. Coordination with the NSF on fundamental research related to critical minerals and materials would allow for leverage of key investments by each agency. DOE is already working with NSF and the Department of Education on the execution of Call to Action 6 in the Federal Strategy (also addressed above). Workforce development efforts would be strengthened through cooperation with NSF, including developing critical minerals and materials curriculum. STEM education and the U.S. higher education system is the best investment for addressing future critical mineral and material supply chain challenges, as well as many other national issues. DOE will take active steps to strengthen the U.S. educational program, paying special attention to nurturing promising student and early career STEM participants who will be the backbone of future innovation. Additionally, DOE will engage with the Department of Commerce to develop mechanisms for international research collaboration and overcome barriers associated with U.S. Competitiveness clauses of Strategic Partnership Agreements. Additionally, DOE will collaborate with other Federal funding agencies to identify where grant opportunities or purchasing opportunities can be co-leveraged with DOE funding or loans.

Objective 4.3: Collaborate with international partners to establish global industry standards;

International Standards for critical minerals and materials are under development and there is a near-term opportunity for DOE, other federal agencies, and international allies to work together to establish leadership on sustainability throughout the critical mineral and material supply chains. These standards will ensure the adoption of best practices for sustainable mining and processing. The International Standards Organization (ISO) currently has a dozen active Technical Committees (TCs) working on critical minerals and materials. DOE is currently engaged in the efforts underway under ISO/TC 333 Lithium and ISO/TC 298 Rare Earth Elements.

In February of 2020, China proposed to ISO the establishment of a new Technical Committee on Lithium. Through standard ISO processes, the proposal was approved. The technical committee, TC 333 on lithium, covers several topics:

- Standardization in the field of lithium mining, concentration, extraction, separation, and conversion to useful lithium compounds/materials (including oxides, salts, metals, master alloys, lithium-ion battery materials, and other materials); and,

- Terminology, technical conditions of delivery to overcome transport difficulties, unified testing, and analysis methods to improve the general quality of lithium products.

Through the American National Standards Institute (ANSI), the U.S. representative to ISO, the United States is in the process of establishing an Administrator and a Chair for a U.S. Technical Advisory Group (TAG) and plans to engage fully in the Technical Committee.

ISO/TC 298 on rare earth elements is also led by China. There are currently seven participating countries in the ISO/TC 298 effort and 22 observing countries. Participating countries who will have a role in voting on draft material are Australia, Canada, China, India, Japan, Korea, and the United States. The scope of the ISO/TC 298 includes:

- Definition of words related to REEs (e.g., common naming conventions);

- Quality control systems (e.g., packaging, labeling, communication methods); and

- Sustainability (e.g., recycling of REE in byproducts and industrial waste, provenance, traceability, and secondary REE products).

A number of standards products are currently under development by ISO/TC 298, ranging from methodological standards on measurement techniques to standards for recycling, packaging, and labeling. Through sustained engagement of experts from the United States who are familiar with the environmental and safety laws that create a sustainable REE supply chain, these high standards can be reflected in ISO/TC 298 and ultimately used and adopted globally. A virtual plenary for ISO/TC 298 was held on September 28–29, 2020. During this meeting, the United States put forward a proposal for standards on sustainability across the supply chain.

In addition to ongoing ISO/TC 333 and ISO/TC 298 efforts, DOE will strengthen its evaluation of other countries' approaches to private industry supply chain issues. As part of the Federal Strategy (recommendation 3.3), DOE will consider partnering with international allies and the private sector to study and evaluate efficient permitting policies now being used in the world's most successful and environmentally friendly mining countries, such

as Australia, Canada, Sweden, and others. The environmental review and permitting processes for producing critical minerals in the United States (including on Federal lands) are governed by regulations of various Federal agencies. The United States has a robust environmental regulatory framework that encompasses the full critical minerals supply chain. A focus on the development of sustainable critical minerals supply chains is unique to developed countries, where environmental laws, worker safety standards, and corporate ethics are designed to produce and use natural resources responsibly. Therefore, a study of the optimal practices to simultaneously protect the environment and increase mineral production will consider full supply chains, from raw material production through end-of-life. Partnering with allies on standards will allow like-minded countries to ensure responsible sourcing, fair-trade practices, and resilient supply chain development to support rapidly increasing demand for these minerals in the coming decades. DOE will also work with multilateral organizations and industry trade groups to shape corporate best practices that are consistent with U.S. foreign and domestic policies, while nurturing communities of practice for methods and innovation.

Conclusion

E.O. 13953 calls for a concerted, whole-of-government effort to re-establish American competitiveness in critical mineral and material supply chains—from mining to processing to manufacturing to recycling. The Department of Energy and its National Laboratories are uniquely positioned to provide leadership and expertise to achieve this goal. By strategically organizing its capabilities and programmatic efforts, DOE will coordinate and focus its efforts addressing key gaps and challenges from fundamental science to commercial adoption.

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Appendix A

List of Authorities

Critical Minerals and Materials Authorities

§ 66 of the Atomic Energy Act of 1954, as amended (42 U.S.C. § 2096), "Source Material", in relevant part (NE and NNSA)

ACQUISITION.—The Commission1 is authorized and directed, to the extent it deems necessary to effectuate the provisions of this Act—

(a) to purchase, take, requisition, condemn, or otherwise acquire supplies of source material;

(b) to purchase, condemn, or otherwise acquire any interest in real property containing deposits of source material; and

(c) to purchase, condemn, or otherwise acquire rights to enter upon any real property deemed by the Commission to have possibilities of containing deposits of source material in order to conduct prospecting and exploratory operations for such deposits.

Note: 1The Energy Reorganization Act in 1974 abolished the Atomic Energy Commission and assigned its "licensing and related regulatory" authority to the Nuclear Regulatory Commission (NRC) and its other functions to the Energy Research and Development Administration (ERDA), which was succeeded by DOE. The Department of Energy Organization Act abolished ERDA and transferred its functions and authorities to the Department of Energy ("DOE"). The term "Commission" in Chapters 6, 7 and 8 have been read to refer to both the NRC and DOE.

§ 31 of the Atomic Energy of 1954, as amended (42 U.S.C. § 2051 "Research Assistance", in relevant part (NNSA)

a. — The Commission is directed to exercise its powers in such manner as to insure the continued conduct of research and development and training activities in fields specified below, by private or public institutions or persons, and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields. To this end the Commission is authorized and directed to make arrangements (including contracts, agreements, and loans) for the conduct of research and development activities relating to—

(1) nuclear processes

(2) the theory and production of atomic energy, including processes, materials, and devices related to such production; . . .

(4) utilization of special nuclear material, atomic energy, and radioactive material and processes entailed in the utilization or production of atomic energy or such material for all other purposes, including industrial or commercial uses, the generation of usable energy, and the demonstration of advances in the commercial or industrial application of atomic energy; . . .

(6) the preservation and enhancement of a viable environment by developing more efficient methods to meet the Nation's energy needs.

§ 2065 of Title 42, American Medical Isotopes Production Act of 2012 "Improving the reliability of domestic medical isotope supply" (NNSA and SC)

(a) MEDICAL ISOTOPE DEVELOPMENT PROJECTS.—

(3) (1) IN GENERAL.— The Secretary shall carry out a technology-neutral program—

(A) to evaluate and support projects for the production in the United States, without the use of highly enriched uranium, of significant quantities of molybdenum-99 for medical uses;

(B) to be carried out in cooperation with non-Federal entities;

§ 67, Atomic Energy Act of 1954, as amended (42 U.S.C. § 2096) "Operations on lands belonging to United States" (NNSA)

The Commission is authorized, to the extent it deems necessary to effectuate the provisions of this chapter, to issue leases or permits for prospecting for, exploration for, mining of, or removal of deposits of source material in lands belonging to the United States: Provided, however, That notwithstanding any other provisions of law, such leases or permits may be issued for lands administered for national park, monument, and wildlife purposes only when the President by Executive Order declares that the

requirements of the common defense and security make such action necessary.

§ 2791-2793 of Title 50, War and National Defense. "Laboratory-directed research and development" (NNSA)

(a) Authority. — Government-owned, contractor-operated laboratories that are funded out of funds available to the Department of Energy for national security programs are authorized to carry out laboratory-directed research and development.

DOE O 413.2C LABORATORY DIRECTED RESEARCH AND DEVELOPMENT

(1) OBJECTIVE. To establish Department of Energy (DOE) requirements for laboratory directed research and development (LDRD) while providing the laboratory director broad flexibility for program implementation. The objectives of the LDRD program are to—

- *foster creativity and stimulate exploration of forefront areas of science and technology;*
- *serve as a proving ground for new concepts in research and development;*
- *support high-risk, potentially high-value research and development.*

§ 2794 of Title 50, War and National Defense. "Critical technology partnerships and cooperative research and development centers" (NNSA)

(a) PARTNERSHIPS.— For the purpose of facilitating the transfer of technology, the Secretary of Energy shall ensure, to the maximum extent practicable, that research on and development of dual-use critical technology carried out through atomic energy defense activities is conducted through cooperative research and development agreements, or other arrangements, that involve laboratories of the Department of Energy and other entities.

§ 2795 of Title 50, War and National Defense. "University-based research collaboration program" (NNSA)

(b) PROGRAM.— The Secretary of Energy shall establish a university program at a location that can develop the most effective collaboration among National Laboratories, universities and colleges, and industry in support of scientific and engineering advancement in key Department of Energy defense and national security program areas.

§ 646 of the Department of Energy Organization Act (Pub. L. 95-91, as amended; 42 U.S.C. § 7256) (Department-wide)

(a) GENERAL AUTHORITY.— The Secretary is authorized to enter into and perform such contracts, leases, cooperative agreements, or other similar transactions with public agencies and private organizations and persons, and to make such payments (in lump sum or installments, and by way of advance or reimbursement) as he may deem to be necessary or appropriate to carry out functions now or hereafter vested in the Secretary.

§ 452 of the Energy Independence and Security Act of 2007 (EISA), as codified at 42 U.S.C. § 17111 (EERE)

(A) ENERGY-INTENSIVE INDUSTRIES PROGRAM.— The Secretary shall establish a program under which the Secretary, in cooperation with energy-intensive industries and national industry trade associations representing the energy-intensive industries, shall support, research, develop, and promote the use of new materials processes, technologies, and techniques to optimize energy efficiency and the economic competitiveness of the United States' industrial and commercial sectors.

§ 656 of EISA, as codified at 42 U.S.C. § 17244 "Renewable Energy Innovation Manufacturing Partnership" (EERE)

(c) PROGRAM PURPOSES.— The purposes of the program are—

(1) to develop, or aid in the development of, advanced manufacturing processes, materials, and infrastructure;

(2) to increase the domestic production of renewable energy technology and components; and

(3) to better coordinate Federal, State, and private resources to meet regional and national renewable energy goals through advanced manufacturing partnerships. 42 U.S.C. § 17244 (c).

(d) ELIGIBLE ENTITIES. — An entity shall be eligible to receive an assistance award under the Program to carry out an eligible project described in subsection (e) if the entity is composed of--

(1) 1 or more public or private nonprofit institutions or National Laboratories engaged in research, development, demonstration, or technology transfer, that would participate substantially in the project; and

(2) 1 or more private entities engaged in the manufacturing or development of renewable energy system components (including solar energy, wind

energy, biomass, geothermal energy, energy storage, or fuel cells). 42 U.S.C. § 17244 (d).

§ 641 of EISA, as codified at 42 U.S.C. § 17231 "Energy Storage Competitiveness" (OE)

(f) BASIC RESEARCH.— The Secretary shall conduct a basic research program on energy storage systems to support electric drive vehicles, stationary applications, and electricity transmission and distribution, including—

(A) materials design;

(B) materials synthesis and characterization;

(C) electrode-active materials, including electrolytes and bioelectrolytes…

§ 911 (a)(2)(C) of the Energy Policy Act of 2005 (EPAct 2005), as codified at 42 U.S.C. § 16191(a)(2)(C) (EERE)

(a) IN GENERAL.— (2) PROGRAMS.— Programs under this subtitle shall include research, development, demonstration, and commercial application of— (C) advanced technologies to improve the energy efficiency, environmental performance, and process efficiency of energy-intensive and waste-intensive industries.

§ 2107 of EPAct 1992, as codified at 42 U.S.C. § 13456 "Improving Efficiency in Energy-Intensive Industries" (EERE)

(a) SECRETARIAL ACTION.— The Secretary, in accordance with Sections 3001 and 3002 of this Act, shall —

(1) pursue a research, development, demonstration, and commercial application program intended to improve energy efficiency and productivity in energy-intensive industries and industrial processes; and

(2) undertake joint ventures to encourage the commercialization of technologies developed under paragraph (1).

Department of Interior and Related Agencies Appropriations Act of 1996, Pub. L. No. 104-134, title 1, § 101(c), 110 Stat. 1321-167 (1996); renumbered title I, Pub. L. 104-140, § 1(a), May 2, 1996, 110 Stat. 1327, as codified at 30 U.S.C. 1 note. (EERE & FE)

(c)TRANSFER OF FUNCTIONS.— That there hereby are transferred to, and vested in, the Secretary of Energy: (1) the functions pertaining to the promotion of health and safety in mines and the mineral industry through research vested by law in the Secretary of the Interior or the United States Bureau of Mines and performed in fiscal year 1995 by the United States Bureau of Mines at its Pittsburgh Research Center in Pennsylvania, and at its Spokane Research Center in Washington; (2) the functions pertaining to the conduct of inquiries, technological investigations and research concerning the extraction, processing, use and disposal of mineral substances vested by law in the Secretary of the Interior or the United States Bureau of Mines and performed in fiscal year 1995 by the United States Bureau of Mines under the minerals and materials science programs at its Pittsburgh Research Center in Pennsylvania, and at its Albany Research Center in Oregon; and (3) the functions pertaining to mineral reclamation industries and the development of methods for the disposal, control, prevention, and reclamation of mineral waste products vested by law in the Secretary of the Interior or the United States Bureau of Mines and performed in fiscal year 1995 by the United States Bureau of Mines at its Pittsburgh Research Center in Pennsylvania: Provided further, That, if any of the same functions were performed in fiscal year 1995 at locations other than those listed above, such functions shall not be transferred to the Secretary of Energy from those other locations: Provided further, That the Director of the Office of Management and Budget, in consultation with the Secretary of Energy and the Secretary of the Interior, is authorized to make such determinations as may be necessary with regard to the transfer of functions which relate to or are used by the Department of the Interior, or component thereof affected by this transfer of functions, and to make such dispositions of personnel, facilities, assets, liabilities, contracts, property, records, and unexpended balances of appropriations, authorizations, allocations, and other funds held, used, arising from, available to or to be made available in connection with, the functions transferred herein as are deemed necessary to accomplish the purposes of this transfer: Provided further, That all reductions in personnel complements resulting from the provisions of this Act shall, as to the functions transferred to the Secretary of Energy, be done by the Secretary of the Interior as though these transfers had not taken place but had been required of the Department of the Interior by all other provisions of this Act before the transfers of function became effective: Provided further, That the transfers of function to the Secretary of Energy shall become effective on the date specified by the Director of the Office of Management and Budget, but in no event later than 90 days after enactment into law of this Act: Provided further, That the reference to "function" includes, but is not limited to, any duty, obligation, power, authority, responsibility,

right, privilege, and activity, or the plural thereof, as the case may be.

§ 5012 of the America COMPETES Act, as codified at 42 U.S.C. § 16538 (ARPA-E)

(b) ESTABLISHMENT.— There is established the Advanced Research Projects Agency—Energy within the Department to overcome the long-term and high-risk technological barriers in the development of energy technologies.

(c) GOALS.—

(1) IN GENERAL.— The goals of ARPA-E shall be—

(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

(2) MEANS.— ARPA-E shall achieve the goals established under paragraph (1) through energy technology projects by—

(A) identifying and promoting revolutionary advances in fundamental sciences;

(B) translating scientific discoveries and cutting-edge inventions into technological innovations; and

(C) accelerating transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty

Public Law 104-134, 110 STAT. 1321–186, Department of Energy, Fossil Energy Research and Development (FE)

For necessary expenses in carrying out fossil energy research and development activities, under the authority of the Department of Energy Organization Act (Public Law 95–91), including the acquisition of interest, including defeasible and equitable interests in any real property or any facility or for plant or facility acquisition or expansion, and for

- *promoting health and safety in mines and the mineral industry through research (30 U.S.C. §§ 3, 861(b), and 951(a)),*
- *for conducting inquiries, technological investigations and research concerning the extraction, processing, use, and disposal of mineral substances without objectionable social and environmental costs (30 U.S.C. §§ 3, 1602, and 1603), and*
- *for the development of methods for the disposal, control, prevention, and reclamation of waste products in the mining, minerals, metal, and mineral reclamation industries (30 U.S.C. §§ 3 and 21a)*

§ 961 of EPAct 2005, as codified at 42 U.S.C. § 16291 "Fossil Energy" (FE)

(a) IN GENERAL

The Secretary shall carry out research, development, demonstration, and commercial application programs in fossil energy, including activities under this part, with the goal of improving the efficiency, effectiveness, and environmental performance of fossil energy production, upgrading, conversion, and consumption. Such programs take into consideration the following objectives:

(1) Increasing the energy conversion efficiency of all forms of fossil energy through improved technologies.

(2) Decreasing the cost of all fossil energy production, generation, and delivery.

(3) Promoting diversity of energy supply.

(4) Decreasing the dependence of the United States on foreign energy supplies.

(5) Improving United States energy security.

(6) Decreasing the environmental impact of energy-related activities.

(7) Increasing the export of fossil energy-related equipment, technology, and services from the United States.

§ 962 of EPAct 2005, as codified at 42 U.S.C. § 16292 "Coal and Related Technologies Program" (FE)

(a) IN GENERAL

In addition to the programs authorized under subchapter IV, the Secretary shall conduct a program of technology research, development, demonstration, and commercial application for coal and power systems, including programs to facilitate production and generation of coal-based power through—

(1) innovations for existing plants (including mercury removal);

(2) gasification systems;

(3) advanced combustion systems;

(4) turbines for synthesis gas derived from coal;

(5) carbon capture and sequestration research and development;

(6) coal-derived chemicals and transportation fuels;

(7) liquid fuels derived from low rank coal water slurry;

(8) solid fuels and feedstocks;

(9) advanced coal-related research;

(10) advanced separation technologies; and

(11) fuel cells for the operation of synthesis gas derived from coal.

§ 964 of EPAct 2005, as codified at 42 U.S.C. § 16294 "Research and Development for Coal Mining Technologies" (FE)

(a) ESTABLISHMENT

The Secretary shall carry out a program for research and development on coal mining technologies.

(b) COOPERATION

In carrying out the program, the Secretary shall cooperate with appropriate Federal agencies, coal producers, trade associations, equipment manufacturers, institutions of higher education with mining engineering departments, and other relevant entities.

(c) PROGRAM

The research and development activities carried out under this section shall—

(1) be guided by the mining research and development priorities identified by the Mining Industry of the Future Program and in the recommendations from relevant reports of the National Academy of Sciences on mining technologies;

(2) include activities exploring minimization of contaminants in mined coal that contribute to environmental concerns including development and demonstration of electromagnetic wave imaging ahead of mining operations;

(3) develop and demonstrate coal bed electromagnetic wave imaging, spectroscopic reservoir analysis technology, and techniques for horizontal drilling in order to—

(A) identify areas of high coal gas content;

(B) increase methane recovery efficiency;

(C) prevent spoilage of domestic coal reserves; and

(D) minimize water disposal associated with methane extraction; and

(4) expand mining research capabilities at institutions of higher education.

§ 1301 of EPAct 1992, codified at 42 U.S.C. § 13331 "Coal Research, Development, Demonstration, and Commercial Application Programs" (FE)

(a) ESTABLISHMENT

The Secretary shall, in accordance with section[s] 13541 and 13542 of this title, conduct programs for research, development, demonstration, and commercial application on coal-based technologies. Such research, development, demonstration, and commercial application programs shall include the programs established under this part, and shall have the goals and objectives of-

(1) ensuring a reliable electricity supply;

(2) complying with applicable environmental requirements;

(3) achieving the control of sulfur oxides, oxides of nitrogen, air toxics, solid and liquid wastes, greenhouse gases, or other emissions resulting from coal use or conversion at levels of proficiency greater than or equal to applicable currently available commercial technology;

(4) achieving the cost competitive conversion of coal into energy forms usable in the transportation sector;

(5) demonstrating the conversion of coal to synthetic gaseous, liquid, and solid fuels;

(6) demonstrating, in cooperation with other Federal and State agencies, the use of coal-derived fuels in mobile equipment, with opportunities for industrial cost sharing participation;

(7) ensuring the timely commercial application of cost-effective technologies or energy production processes or systems utilizing coal which achieve-

(A) greater efficiency in the conversion of coal to useful energy when compared to currently available commercial technology for the use of coal; and

(B) the control of emissions from the utilization of coal; and

(8) ensuring the availability for commercial use of such technologies by the year 2010.

(b) DEMONSTRATION AND COMMERCIAL APPLICATION PROGRAMS

(1) In selecting either a demonstration project or a commercial application project for financial assistance under this part, the Secretary shall seek to ensure that, relative to otherwise comparable commercially available technologies or products, the selected project will meet one or more of the following criteria:

(A) It will reduce environmental emissions to an extent greater than required by applicable provisions of law.

(B) It will increase the overall efficiency of the utilization of coal, including energy conversion efficiency and, where applicable, production of products derived from coal.

(C) It will be a more cost-effective technological alternative, based on life cycle capital and operating costs per unit of energy produced and, where applicable, costs per unit of product produced

§ 1303 of EPAct 1992, codified at 42 U.S.C. § 13333 "Clean Coal, Waste-to-Energy" (FE)

The Secretary shall establish a program of research, development, demonstration, and commercial application with respect to the use of solid waste combined with coal as a fuel source for clean coal combustion technologies. The program shall address-

(1) the feasibility of cofiring coal and used vehicle tires in fluidized bed combustion units;

(2) the combined gasification of coal and municipal sludge using integrated gasification combined cycle technology;

(3) the creation of fuel pellets combining coal and material reclaimed from solid waste;

(4) the feasibility of cofiring, in fluidized bed combustion units, waste methane from coal mines, including ventilation air, together with coal or coal wastes; and

(5) other sources of waste and coal mixtures in other applications that the Secretary considers appropriate.

§ 1304 of EPAct 1992, codified at 42 U.S.C. § 13334 "Nonfuel Use of Coal" (FE)

(a) PROGRAM

The Secretary shall prepare a plan for and carry out a program of research, development, demonstration, and commercial application with respect to technologies for the nonfuel use of coal, including-

(1) production of coke and other carbon products derived from coal;

(2) production of coal-derived, carbon-based chemical intermediates that are precursors of value-added chemicals and polymers;

(3) production of chemicals from coal-derived synthesis gas;

(4) coal treatment processes, including methodologies such as solvent-extraction techniques that produce low ash, low sulfur, coal-based chemical feedstocks; and

(5) waste utilization, including recovery, processing, and marketing of products derived from sulfur, carbon dioxide, nitrogen, and ash from coal.

(b) PLAN CONTENTS

The plan described in subsection (a) shall address and evaluate-

(1) the known and potential processes for using coal in the creation of products in the chemical, utility, fuel, and carbon-based materials industries;

(2) the costs, benefits, and economic feasibility of using coal products in the chemical and materials industries, including value-added chemicals, carbon-based products, coke, and waste derived from coal;

(3) the economics of coproduction of products from coal in conjunction with the production of electric power, thermal energy, and fuel;

(4) the economics of the refining of coal and coal byproducts to produce nonfuel products;

(5) the economics of coal utilization in comparison with other feedstocks that might be used for the same purposes;

(6) the steps that can be taken by the public and private sectors to bring about commercialization of technologies developed under the program recommended; and

(7) the past development, current status, and future potential of coal products and processes associated with nonfuel uses of coal.

§ 1310 of EPAct 1992, codified at 42 U.S.C. § 13340 "Low-Rank Coal Research and Development" (FE)

The Secretary shall pursue a program of research and development with respect to the technologies needed to expand the use of low-rank coals which take into account the unique properties of lignites and sub-bituminous coals, including, but not limited to, the following areas-

(1) high value-added carbon products;

(2) fuel cell applications;

(3) emissions control and combustion efficiencies;

(4) coal water fuels and underground coal gasification;

(5) distillates; and

(6) any other technologies which will assist in the development of niche markets for lignites and sub-bituminous coals.

Public Law 104-208, 110 STAT. 3009-210, Fossil Energy Research and Development (FE)

For necessary expenses in carrying out fossil energy research and development activities, under the authority of the Department of Energy Organization Act (Public Law 95–91), including the acquisition of interest, including defeasible and equitable interests in any real property or any facility or for plant or facility

acquisition or expansion, and for conducting inquiries, technological investigations and research concerning the extraction, processing, use, and disposal of mineral substances without objectionable social and environmental costs (30 U.S.C. §§ 3, 1602, and 1603), performed under the minerals and materials science programs at the Albany Research Center in Oregon, $364,704,000, to remain available until expended: Provided, That no part of the sum herein made available shall be used for the field testing of nuclear explosives in the recovery of oil and gas.

Public Law 116-94, 13 STAT. 2670, Fossil Energy Research and Development (FE)

For Department of Energy expenses necessary in carrying out fossil energy research and development activities, under the authority of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), including the acquisition of interest, including defeasible and equitable interests in any real property or any facility or for plant or facility acquisition or expansion, and for conducting inquiries, technological investigations and research concerning the extraction, processing, use, and disposal of mineral substances without objectionable social and environmental costs (30 U.S.C. 3, 1602, and 1603), $750,000,000, to remain available until expended: Provided, That of such amount $61,500,000 shall be available until September 30, 2021, for program direction.

Section 101(c) of the Defense Production Act of 1950 (Department-wide)

(A) …the Secretary of Energy must find that the desired materials, services, or facilities are critical and essential (1) to maintain or expand exploration, production, refining, transportation; (2) to conserve energy supplies; or (3) to construct or maintain energy facilities. The Secretary of Commerce must then find that the desired materials, services, or facilities are scarce and that the "critical and essential" need cannot be reasonably accomplished absent use of section 101(c) authorities.

30 U.S.C. § 1602. Congressional declaration of policies and § 1603. Implementation of policies (Materials and Minerals Policy, Research, and Development Act of 1980) (Department-wide)

§ 1602. The Congress declares that it is the continuing policy of the United States to promote 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 between resource production, energy use, a healthy environment, natural resources conservation, and social needs. The Congress further declares that implementation of this policy requires that the President shall, through the Executive Office of the President, coordinate the responsible departments and agencies to, among other measures—

(1) identify materials needs and assist in the pursuit of measures that would assure the availability of materials critical to commerce, the economy, and national security;

(2) establish a mechanism for the coordination and evaluation of Federal materials programs, including those involving research and development so as to complement related efforts by the private sector as well as other domestic and international agencies and organizations;

(3) establish a long-range assessment capability concerning materials demands, supply and needs, and provide for the policies and programs necessary to meet those needs;

(4) promote a vigorous, comprehensive, and coordinated program of materials research and development consistent with the policies and priorities set forth in the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 et seq.);

(5) promote cooperative research and development programs with other nations for the equitable and frugal use of materials and energy;

(6) promote and encourage private enterprise in the development of economically sound and stable domestic materials industries; and

(7) encourage Federal agencies to facilitate availability and development of domestic resources to meet critical materials needs.

§ 1603. For the purpose of implementing the policies set forth in section 1602 of this title and the provisions of section 1604 of this title, the Congress declares that the President shall, through the Executive Office of the President, coordinate the responsible departments and agencies, and shall—

(1) direct that the responsible departments and agencies identify, assist, and make recommendations for carrying out appropriate policies and programs to ensure adequate, stable, and economical materials supplies essential to national security, economic well-being, and industrial production;

(2) support basic and applied research and development to provide for, among other objectives—

(A) advanced science and technology for the exploration, discovery, and recovery of nonfuel materials;

(B) enhanced methods or processes for the more efficient production and use of renewable and nonrenewable resources;

(C) improved methods for the extraction, processing, use, recovery, and recycling of materials which encourage the conservation of materials, energy, and the environment; and

(D) improved understanding of current and new materials performance, processing, substitution, and adaptability in engineering designs;

(3) provide 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;

(4) assess the need for and make recommendations concerning the availability and adequacy of 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;

(5) establish early warning systems for materials supply problems;

(6) recommend to the Congress appropriate measures to promote industrial innovation in materials and materials technologies;

(7) encourage cooperative materials research and problem-solving by—

(A) private corporations performing the same or related activities in materials industries; and

(B) Federal and State institutions having shared interests or objectives;

(8) assess Federal policies which adversely or positively affect all stages of the materials cycle, from exploration to final product recycling and disposal including but not limited to, financial assistance and tax policies for recycled and virgin sources of materials and make recommendations for equalizing any existing imbalances, or removing any impediments, which may be created by the application of Federal law and regulations to the market for materials; and

(9) assess the opportunities for the United States to promote cooperative multilateral and bilateral agreements for materials development in foreign nations for the purpose of increasing the reliability of materials supplies to the Nation.

§ 1301 of EISA, as codified at 42 U.S.C. § 17381, "Statement of policy on modernization of electricity grid" (Department-wide)

It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

(1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.

(2) Dynamic optimization of grid operations and resources, with full cyber-security.

(3) Deployment and integration of distributed resources and generation, including renewable resources.

(4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.

(5) Deployment of "smart" technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.

(6) Integration of "smart" appliances and consumer devices.

(7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning . . . .

Executive Order 13920 of May 1, 2020, "Securing the United States Bulk-Power System," (85 FR 26595 (May 4, 2020)) (OE)

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the International Emergency Economic Powers Act (50 U.S.C. 1701 et seq.) (IEEPA), the National Emergencies Act (50 U.S.C. 1601 et seq.) (NEA), and section 301 of title 3, United States Code,

I, DONALD J. TRUMP, President of the United States of America, find that foreign adversaries are increasingly creating and exploiting vulnerabilities in the United States bulk-power system, which provides the electricity that supports our national defense, vital emergency services, critical infrastructure, economy, and way of life. The bulk-power system is a target of

those seeking to commit malicious acts against the United States and its people, including malicious cyber activities, because a successful attack on our bulk-power system would present significant risks to our economy, human health and safety, and would render the United States less capable of acting in defense of itself and its allies. I further find that the unrestricted acquisition or use in the United States of bulk-power system electric equipment designed, developed, manufactured, or supplied by persons owned by, controlled by, or subject to the jurisdiction or direction of foreign adversaries augments the ability of foreign adversaries to create and exploit vulnerabilities in bulk-power system electric equipment, with potentially catastrophic effects. I therefore determine that the unrestricted foreign supply of bulk-power system electric equipment constitutes an unusual and extraordinary threat to the national security, foreign policy, and economy of the United States, which has its source in whole or in substantial part outside the United States. This threat exists both in the case of individual acquisitions and when acquisitions are considered as a class. Although maintaining an open investment climate in bulk-power system electric equipment, and in the United States economy more generally, is important for the overall growth and prosperity of the United States, such openness must be balanced with the need to protect our Nation against a critical national security threat. To address this threat, additional steps are required to protect the security, integrity, and reliability of bulk-power system electric equipment used in the United States. In light of these findings, I hereby declare a national emergency with respect to the threat to the United States bulk-power system . . .

Section 1. Prohibitions and Implementation.

(a) The following actions are prohibited: any acquisition, importation, transfer, or installation of any bulk-power system electric equipment (transaction) by any person, or with respect to any property, subject to the jurisdiction of the United States, where the transaction involves any property in which any foreign country or a national thereof has any interest (including through an interest in a contract for the provision of the equipment), where the transaction was initiated after the date of this order, and where the Secretary of Energy (Secretary), in coordination with the Director of the Office of Management and Budget and in consultation with the Secretary of Defense, the Secretary of Homeland Security, the Director of National Intelligence, and, as appropriate, the heads of other executive departments and agencies (agencies), has determined that:

(i) the transaction involves bulk-power system electric equipment designed, developed, manufactured, or supplied, by persons owned by, controlled by, or subject to the jurisdiction or direction of a foreign adversary; and

(ii) the transaction:

(A) poses an undue risk of sabotage to or subversion of the design, integrity, manufacturing, production, distribution, installation, operation, or maintenance of the bulk-power system in the United States;

(B) poses an undue risk of catastrophic effects on the security or resiliency of United States critical infrastructure or the economy of the United States; or

(C) otherwise poses an unacceptable risk to the national security of the United States or the security and safety of United States persons.

(b) The Secretary, in consultation with the heads of other agencies as appropriate, may at the Secretary's discretion design or negotiate measures to mitigate concerns identified under section 1(a) of this order. Such measures may serve as a precondition to the approval by the Secretary of a transaction or of a class of transactions that would otherwise be prohibited pursuant to this order.

(c) The prohibitions in subsection 9a) of this section apply except to the extent provided by statutes, or in regulations, orders, directives, or licenses that may be issued pursuant to this order, and notwithstanding any contract entered into or any license or permit granted prior to the date of this order.

(d) The Secretary, in consultation with the heads of other agencies as appropriate, may establish and publish criteria for recognizing particular equipment and particular vendors in the bulk-power system electric equipment market as pre-qualified for future transactions; and may apply these criteria to establish and publish a list of pre-qualified equipment and vendors. Nothing in this provision limits the Secretary's authority under this section to prohibit or otherwise regulate any transaction involving pre-qualified equipment or vendors.

Sect. 2. Authorities.

(a) The Secretary is hereby authorized to take such actions, including directing the timing and manner of the cessation of pending and future transactions prohibited pursuant to section 1 of this order, adopting appropriate rules and regulations, and employing all other powers granted to the President by IEEPA as may be necessary to implement this order. The heads of all agencies, including the Board of Directors of the

Tennessee Valley Authority, shall take all appropriate measures within their authority as appropriate and consistent with applicable law, to implement this order.

(b) Rules and regulations issued pursuant to this order may, among other things, determine that particular countries or persons are foreign adversaries exclusively for the purposes of this order; identify persons owned by, controlled by, or subject to the jurisdiction or direction of foreign adversaries exclusively for the purposes of this order; identify particular equipment or countries with respect to which transactions involving bulk-power system electric equipment warrant particular scrutiny under the provisions of this order; establish procedures to license transactions otherwise prohibited pursuant to this order; and identify a mechanism and relevant factors for the negotiation of agreements to mitigate concerns raised in connection with subsection 1(a) of this order. Within 150 days of the date of this order, the Secretary, in consultation with the Secretary of Defense, the Secretary of Homeland Security, the Director of National Intelligence, and, as appropriate, the heads of other agencies, shall publish rules or regulations implementing the authorities delegated to the Secretary by this order.

(c) The Secretary may, consistent with applicable law, redelegate any of the authorities conferred on the Secretary pursuant to this section within the Department of Energy.

(d) As soon as practicable, the Secretary, in consultation with the Secretary of Defense, the Secretary of the Interior, the Secretary of Homeland Security, the Director of National Intelligence, the Board of Directors of the Tennessee Valley Authority, and the heads of such other agencies as the Secretary considers appropriate, shall:

(i) identify bulk-power system electric equipment designed, developed, manufactured, or supplied, by persons owned by, controlled by, or subject to the jurisdiction or direction of a foreign adversary that poses an undue risk of sabotage to or subversion of the design, integrity, manufacturing, production, distribution, installation, operation, or maintenance of the bulk-power system in the United States, poses an undue risk of catastrophic effects on the security or resiliency of United States critical infrastructure or the economy of the United States, or otherwise poses an unacceptable risk to the national security of the United States or the security and safety of United States persons; and

(ii) develop recommendations on ways to identify, isolate, monitor, or replace such items as soon as practicable, taking into consideration overall risk to the bulk-power system.

Sec. 3. Task Force on Federal Energy Infrastructure Procurement Policies Related to National Security . . .

(c) The Task Force shall:

(i) develop a recommended consistent set of energy infrastructure procurement policies and procedures for agencies, to the extent consistent with law, to ensure that national security considerations are fully integrated across the Federal Government, and submit such recommendations to the Federal Acquisition Regulatory Council (FAR Council);

(ii) evaluate the methods and criteria used to incorporate national security considerations into energy security and cybersecurity policymaking;
(iii) consult with the Electricity Subsector Coordinating Council and the Oil and Natural Gas Subsector Coordinating Council in developing the recommendations and evaluation described in subsections (c)(i) through (ii) of this section; and
(iv) conduct any other studies, develop any other recommendations, and submit any such studies and recommendations to the President, as appropriate and as directed by the Secretary . . .

(h) Because attacks on the bulk-power system can originate through the distribution system, the Task Force shall engage with distribution system industry groups, to the extent consistent with law and national security. Within 180 days of receiving the recommendations pursuant to subsection (c)(i) of this section, the FAR Council shall consider proposing for notice and public comment an amendment to the applicable provisions in the Federal Acquisition Regulation to implement the recommendations provided pursuant to subsection (c)(i) of this section.

Sec. 4. Definitions. For purposes of this order, the following definitions shall apply:

(a) The term "bulk-power system" means (i) facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof); and (ii) electric energy from generation facilities needed to maintain transmission reliability. For the purpose of this order, this definition includes transmission lines rated at 69,000 volts (69 kV) or more but does not include facilities used in the local distribution of electric energy.

(b) The term "bulk-power system electric equipment" means items used in bulk-power system substations, control rooms, or power generating stations, including reactors, capacitors, substation transformers, current coupling capacitors, large generators, backup generators, substation voltage regulators, shunt

capacitor equipment, automatic circuit reclosers, instrument transformers, coupling capacity voltage transformers, protective relaying, metering equipment, high voltage circuit breakers, generation turbines, industrial control systems, distributed control systems, and safety instrumented systems. Items not included in the preceding list and that have broader application of use beyond the bulk-power system are outside the scope of this order.

(c) The term ''entity'' means a partnership, association, trust, joint venture, corporation, group, subgroup, or other organization.

(d) The term ''foreign adversary'' means any foreign government or foreign non-government person engaged in a long-term pattern or serious instances of conduct significantly adverse to the national security of the United States or its allies or the security and safety of United States persons.

(e) The term ''person'' means an individual or entity.

(f) The term ''procurement'' means the acquiring by contract with appropriated funds of supplies or services, including installation services, by and for the use of the Federal Government, through purchase, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated.

(g) The term ''United States person'' means any United States citizen, permanent resident alien, entity organized under the laws of the United States or any jurisdiction within the United States (including foreign branches), or any person in the United States.

Sec. 5. Recurring and Final Reports to the Congress. The Secretary is hereby authorized to submit recurring and final reports to the Congress regarding the national emergency declared in this order, consistent with section 401(c) of the NEA (50 U.S.C. 1641(c)) and section 204(c) of IEEPA (50 U.S.C. 1703(c)) . . .

Executive Order 13953 of September 30, 2020, "Addressing the Threat to the Domestic Supply Chain From Reliance on Critical Minerals From Foreign Adversaries and Supporting the Domestic Mining and Processing Industries," (85 FR 26595 (May 4, 2020)) (Department-wide)

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the International Emergency Economic Powers Act (50 U.S.C. 1701 et seq.) (IEEPA), the National Emergencies Act (50 U.S.C. 1601 et seq.) (NEA), and section 301 of title 3, United States Code, I, DONALD J. TRUMP, President of the United States of America, find that a strong America cannot be dependent on imports from foreign adversaries for the critical minerals that are increasingly necessary to maintain our economic and military strength in the 21st century. Because of the national importance of reliable access to critical minerals, I signed Executive Order 13817 of December 20, 2017 (A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals), which required the Secretary of the Interior to identify critical minerals and made it the policy of the Federal Government "to reduce the Nation's vulnerability to disruptions in the supply of critical minerals." Pursuant to my order, the Secretary of the Interior conducted a review with the assistance of other executive departments and agencies (agencies) that identified 35 minerals that (1) are "essential to the economic and national security of the United States," (2) have supply chains that are "vulnerable to disruption," and (3) serve "an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or our national security."

These critical minerals are necessary inputs for the products our military, national infrastructure, and economy depend on the most. Our country needs critical minerals to make airplanes, computers, cell phones, electricity generation and transmission systems, and advanced electronics. Though these minerals are indispensable to our country, we presently lack the capacity to produce them in processed form in the quantities we need. American producers depend on foreign countries to supply and process them. For 31 of the 35 critical minerals, the United States imports more than half of its annual consumption. The United States has no domestic production for 14 of the critical minerals and is completely dependent on imports to supply its demand. Whereas the United States recognizes the continued importance of cooperation on supply chain issues with international partners and allies, in many cases, the aggressive economic practices of certain non-market foreign producers of critical minerals have destroyed vital mining and manufacturing jobs in the United States.

Our dependence on one country, the People's Republic of China (China), for multiple critical minerals is particularly concerning. The United States now imports 80 percent of its rare earth elements directly from China, with portions of the remainder indirectly sourced from China through other countries. In the 1980s, the United States produced more of

these elements than any other country in the world, but China used aggressive economic practices to strategically flood the global market for rare earth elements and displace its competitors. Since gaining this advantage, China has exploited its position in the rare earth elements market by coercing industries that rely on these elements to locate their facilities, intellectual property, and technology in China. For instance, multiple companies were forced to add factory capacity in China after it suspended exports of processed rare earth elements to Japan in 2010, threatening that country's industrial and defense sectors and disrupting rare earth elements prices worldwide.

The United States also disproportionately depends on foreign sources for barite. The United States imports over 75 percent of the barite it consumes, and over 50 percent of its barite imports come from China. Barite is of critical importance to the hydraulic fracturing ("fracking") industry, which is vital to the energy independence of the United States. The United States depends on foreign sources for 100 percent of its gallium, with China producing around 95 percent of the global supply. Gallium based semiconductors are indispensable for cellphones, blue and violet light-emitting diodes (LEDs), diode lasers, and fifth generation (5G) telecommunications. Like for gallium, the United States is 100 percent reliant on imports for graphite, which is used to make advanced batteries for cellphones, laptops, and hybrid and electric cars. China produces over 60 percent of the world's graphite and almost all of the world's production of high-purity graphite needed for rechargeable batteries.

For these and other critical minerals identified by the Secretary of the Interior, we must reduce our vulnerability to adverse foreign government action, natural disaster, or other supply disruptions. Our national security, foreign policy, and economy require a consistent supply of each of these minerals.

I therefore determine that our Nation's undue reliance on critical minerals, in processed or unprocessed form, from foreign adversaries constitutes an unusual and extraordinary threat, which has its source in substantial part outside the United States, to the national security, foreign policy, and economy of the United States. I hereby declare a national emergency to deal with that threat.

In addition, I find that the United States must broadly enhance its mining and processing capacity, including for minerals not identified as critical minerals and not included within the national emergency declared in this order. By expanding and strengthening domestic mining and processing capacity today, we guard against the possibility of supply chain disruptions and future attempts by our adversaries or strategic competitors to harm our economy and military readiness. Moreover, additional domestic capacity will reduce United States and global dependence on minerals produced in countries that do not endorse and pursue appropriate minerals supply chain standards, leading to human rights violations, forced and child labor, violent conflict, and health and environmental damage. Finally, a stronger domestic mining and processing industry fosters a healthier and faster growing economy for the United States. Mining and mineral processing provide jobs to hundreds of thousands of Americans whose daily work allows our country and the world to "Buy American" for critical technology.

I hereby determine and order . . .

Sec. 2 (a). It is the policy of the United States that relevant agencies should, as appropriate and consistent with applicable law, prioritize the expansion and protection of the domestic supply chain for minerals and the establishment of secure critical minerals supply chains, and should direct agency resources to this purpose, such that:

(i) the United States develops secure critical minerals supply chains that do not depend on resources or processing from foreign adversaries;

(ii) the United States establishes, expands, and strengthens commercially viable critical minerals mining and mineral processing capabilities; and

(iii) the United States develops globally competitive, substantial, and resilient domestic commercial supply chain capabilities for critical minerals mining and processing.

(b) Within 30 days of the date of this order, the heads of all relevant agencies shall each submit a report to the President, through the Director of the Office of Management and Budget . . . that identifies all legal authorities and appropriations that the agency can use to meet the goals identified in subsection (a) of this section.

(c) Within 60 days of the date of this order, the heads of all relevant agencies shall each submit a report as provided in subsection (b) of this section that details the agency's strategy for using the legal authorities and appropriations identified pursuant to that subsection to meet the goals identified in subsection 9a) of this section. The report shall explain how the agency's activities will be organized and how it proposes to coordinate relevant activities with other agencies.

Sec. 4. (a) Within 30 days of the date of this order, the Secretary of Energy shall develop and publish guidance (and, as appropriate, shall revoke, revise, or replace prior guidance, including loan solicitations) clarifying the extent to which projects that support domestic supply chains for minerals are eligible for loan guarantees pursuant to Title XVII of the Energy Policy Act of 2005, as amended (42 U.S.C. 16511 et seq.) ("Title XVII"), and for funding awards and loans pursuant to the Advanced Technology Vehicles Manufacturing incentive program established by section 136 of the Energy Independence and Security Act of 2007, as amended (42 U.S.C. 17013) ("the ATVM statute"). In developing such guidance, the Secretary:

(i) shall consider whether the relevant provisions of Title XVII can be interpreted in a manner that better promotes the expansion and protection of the domestic supply chain for minerals (including the development of new supply chains and the processing, remediation, and reuse of materials already in interstate commerce or otherwise available domestically);

(ii) shall examine the meaning of the terms "avoid, reduce, or sequester" and other key terms in section 16513(a) of title 42, United States Code, which provides that the Secretary "may make guarantees under this section only for projects that_(1) avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases; and (2) employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued";

(iii) shall consider whether relevant provisions of the ATVM statute may be interpreted in a manner that better promotes the expansion and protection of the domestic supply chain for minerals (including the development of new supply chains and the processing, remediation, and reuse of materials already in interstate commerce or otherwise available domestically), including in such consideration the application of these provisions to minerals determined to be components installed for the purpose of meeting the performance requirements of advanced technology vehicles; and

*(iv) shall examine the meaning of the terms "qualifying components" and other key terms in subsection 17013(a) of *62543 title 42, United States Code.*

(b) Within 30 days of the date of this order, the Secretary of Energy shall review the Department of Energy's regulations (including any preambles thereto) interpreting Title XVII and the ATVM statute, including the regulations published at 81 Fed. Reg. 90,699 (Dec. 15, 2016) and 73 Fed. Reg. 66,721 (Nov. 12, 2008), and shall identify all such regulations that may warrant revision or reconsideration in order to expand and protect the domestic supply chain for minerals (including the development of new supply chains and the processing, remediation, and reuse of materials already in interstate commerce or otherwise available domestically). Within 90 days of the date of this order, the Secretary shall propose for notice and comment a rule or rules to revise or reconsider any such regulations for this purpose, as appropriate and consistent with applicable law...

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