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Critical Minerals: Why is Uranium on the List?

Statement Prepared for Hearing on Uranium Mining: Contamination and Criticality
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Introduction

Concerns about dependence on foreign supply chains of certain commodities are as old as international trade. When commodities are considered vital to a country's security or economic prosperity, concerns especially rise if the foreign supply chains are vulnerable to disruption for natural or contrived reasons. A key consideration is the level of import dependence, sometimes called net import reliance, but there are additional factors to consider.[1]

For modern economies, reliance on high technology communications means reliance on mineral commodities. For example, more than half of all components in mobile devices rely on minerals for electronics: displays, batteries, speakers and vibration motors. The ubiquitous cell phone has small quantities of germanium, indium, lithium, platinum, tantalum, and tungsten, sourced from every continent save Antarctica.[2] The tenfold increase in the number of cell phones alone since 2000 (with subscriptions rising from about 735 million to more than 7 billion today) has increased the pressure to find cheaper and more sustainable resources.[3]

The security and sustainability of non-fuel mineral resources, including rare earth elements, is therefore a concern for many countries. Sudden supply disruptions, like China's ban on exports of rare earth metals to Japan during a dispute in the South China Sea in 2010, can be unnerving.[4] Whether this rises to the level of damaging economic and national security is not clear. In the 2010 dispute, the impact on Japan was short-lived. One thing is clear from the 2010 embargo, however: China's dominance in production of rare earth elements has dropped from 95% to about 71% of the global total.[5] And although China recently issued threats of a similar embargo against the United States, some analysts believe an embargo would hurt China as well.[6] Such an embargo could actually raise prices and stimulate the development of resources in other countries, including the United States.

The example of China and the production of rare earth elements suggests that crafting an industrial policy to achieve trade and defense policy aims driven by a narrow focus on dependence on overseas raw materials may be short-sighted and ultimately ineffective. Mineral

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[1] Net import reliance measures imports as a percentage of consumption. To compare net import reliance of various non-fuel minerals, see https://www.usgs.gov/news/risk-and-reliance-us-economy-and-mineral-resources.

[2] Commercial mining is banned in the Antarctic until 2048 by Article 7 of the Protocol on the Environmental Protection to the Antarctic Treaty. A future treaty that established a regulatory framework would be required to lift the ban on commercial mining.

[3] Cell phone subscriptions per 100 people rose from 12 in 2000 to more than 100. See https://data.worldbank.org/indicator/IT.CEL.SETS.P2.

[4] https://www.nytimes.com/2010/09/23/business/global/23rare.html

[5] https://pubs.usgs.gov/circ/1454/circ1454.pdf

[6] https://www.forbes.com/sites/timtreadgold/2019/06/12/china-risks-damaging-its-rare-earth-industry-if-it-puts-an-embargo-on-exports-to-the-u-s/#1318882f5611

resource availability often rises with commodity prices (that is, increasing to meet demand/price because previously uneconomic deposits become recoverable). Efforts to shore up supply artificially like propping up domestic production for political reasons may have the opposite of the intended effect. Overall, such an approach is unsustainable and uneconomic in the long run, detracting from rather than enhancing national and economic security.

The Trump Administration's Approach

At the end of 2017, President Trump directed the executive branch to develop a strategy to secure reliable supplies of critical minerals. Many of these minerals, which include the well-known rare-earth elements crucial to advanced computing systems, are produced overseas. In the case of 14 minerals, the United States has relied entirely on foreign sources. Executive Order 13817 on "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," issued December 20, 2017, aimed to address a purported "strategic vulnerability ... to adverse foreign government action, natural disaster, and other events that can disrupt supply of these key minerals." Working from a list of 35 critical minerals compiled by the Department of Interior, the federal government has been directed to develop policies to increase private-sector "domestic exploration, production, recycling, and reprocessing of critical minerals, and support for efforts to identify more commonly available technological alternatives to these minerals" in an effort to "reduce our dependence on imports, preserve our leadership in technological innovation, support job creation, improve our national security and balance of trade, and enhance the technological superiority and readiness of our Armed Forces, which are among the Nation's most significant consumers of critical minerals."[7]

The Secretary of the Interior began the process by identifying "critical minerals," defined as non-fuel minerals that serve essential economic or national security functions, are vulnerable to supply chain disruption, and that 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." The Secretary of Commerce then prepared a report on strategies to reduce U.S. reliance on critical minerals identified by the Secretary of the Interior.

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[7] Executive Order No. 13817 on a Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, December 20, 2017. See https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals.

Executive Order 13817 suggested several strategies for reducing reliance on critical minerals to be included in this report: the development of reprocessing or replacement technologies; increasing mineral access through trade relationships with allies; and encouraging domestic private sector mineral exploration, production, and refinement. Special emphasis is placed on other efforts to reduce regulatory burdens on the domestic production of mineral and energy resources: Executive Order 13771 of January 30, 2017 (Reducing Regulation and Controlling Regulatory Costs), Executive Order 13783 of March 28, 2017 (Promoting Energy Independence and Economic Growth), Executive Order 13807 of August 15, 2017 (Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects), and Executive Order 12866 of September 30, 1993 (Regulatory Planning and Review).

The Critical Minerals List, published on February 16, 2018, included: aluminum, antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite, 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.

Public comments predictably suggested adding or subtracting minerals from the list. One-third of the 566 comments, however, objected to the inclusion of uranium on the list because it is a fuel source. The Department of the Interior made no changes, while affirming that the list was subject to change, and issued the final list on May 18, 2018. It did address, however, the comments about uranium, stating that the non-fuel uses of uranium warranted its inclusion on the list as a non-fuel critical mineral.

Uranium as a Non-Fuel Mineral?

Classifying uranium as a non-fuel mineral is a departure from precedent. For example, the *Mineral Commodities Summaries*, an annual publication by the Department of the Interior and the U.S. Geological Survey, supplies exhaustive data on over 90 non-fuel minerals and has not included uranium in its study for the past twenty years.[8] Part of the reason may be that uranium has been classified as mineral fuel since the 1970 Mining and Minerals Policy Act. In 2016, the National Science and Technology Council (NSTC) designed a quantitative approach to assess the criticality of non-fuel minerals in its report, *Assessment of Critical Minerals: Screening Methodology and Initial Application*. According to the Summary of Methodology and Background Information provided by the DOI and the USGS, the methodology used in the NSTC report was the foundation of the DOI's critical minerals list. As the DOI and USGS themselves acknowledge, the NSTC report focused on “nonfuel minerals and, thus, did not include uranium.” The National Academy of Science's *Minerals, Critical Minerals, and the U.S. Economy* (2008) does include uranium in its analysis of critical minerals, but as an explicit exception to its focus on non-fuel minerals (uranium is not deemed a critical mineral in its subsequent analysis).

The DOI and USGS cited all of the above resources in its Summary of Methodology and Background Information and yet still included uranium in the Critical Minerals List.

The Department of Interior, in its response to public comments, cited existing government sources such as the USGS Open-File Report 2018-1021 to support its claim that non-fuel uses warrant the inclusion of uranium on the Critical Minerals List. A closer examination of the non-fuel purposes listed in that report reveals that aerospace, defense and energy uses are actually all related to using uranium in fuel. Under the heading of aerospace, the USGS report mentions space missions. The space program uses LEU as fuel for propulsion of space

[8] https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

vehicles and is considering using HEU as fuel for a surface-powered reactor.[9] NASA also uses Pu-238 as radiothermal power generators or RPGs (Pu-238 can be made by irradiating U-238 to produce Np-238 which decays into Pu-238 or by irradiating Np-237 directly, which is how it is done now). RPGs "convert heat from the natural radioactive decay of the isotope plutonium-238 (used in a ceramic form of plutonium dioxide) into electrical power to operate the computers, science instruments, and other hardware aboard NASA missions such as the Curiosity rover on Mars and the New Horizons spacecraft flyby of Pluto and beyond."[10] All of those uses are fuel-related. There may be other uses of uranium that NASA has not revealed publicly.

As for defense needs, the biggest non-fuel related use for uranium is for U.S. (and UK) nuclear weapons. The total U.S. HEU inventory was 585.6 tons in 2013,[11] enough to make more than 23,000 nuclear weapons, so there is presumably no need for additional production. The United States stopped producing HEU for weapons purposes in 1964 and for all other purposes in 1992 and stopped producing plutonium for weapons purposes in 1989. There is no reasonable scenario of great power competition that would justify a return to fissile material production for weapons purposes, and the United States has maintained a policy since 1992 of not producing fissile material for nuclear weapons and of seeking a treaty to ban such production in the future.

There are, of course, other uses for uranium for defense purposes. The U.S. military, for example, has used depleted uranium for armor-plating and armor-piercing projectiles for the past few decades. Depleted uranium is a by-product of uranium enrichment (essentially, the tails of the process). The United States holds approximately 40 percent of the global stockpile.

Other military uses of uranium include naval propulsion and LEU used as fuel to produce tritium, but these are obviously fuel purposes. Finally, producing radioisotopes for medical purposes essentially requires uranium to fuel the reactors (or they can be produced in accelerators), but a small amount of HEU has been used in the past as targets for producing Molybdenum-99, a radioisotope used in medical diagnostic procedures. These are gram quantities (one producer has used 3.7 grams HEU per target or 16.6 grams of LEU per target). Whether HEU or LEU is used for targets to produce Mo-99, the amount of material for this non-fuel use is very small compared to its fuel uses.

Uranium: A Strategic but not Critical Mineral

Until scientists realized the strategic importance of uranium to the development of nuclear weapons, uranium was simply a byproduct of mining for radium and vanadium in the United States. The uranium for the first U.S. atomic bombs came from Canada, the Belgian Congo, South Africa and Australia. For the first seven years of the U.S. nuclear weapons program,

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[9] See Alan Kuperman and Ed Lyman, "Why is NASA testing bomb-grade materials for its Mars Mission?" Baltimore Sun, August 20, 2017, https://www.baltimoresun.com/opinion/op-ed/bs-ed-op-0821-nasa-uranium-20170815-story.html.

[10] See https://rps.nasa.gov/about-rps/about-plutonium-238/.

[11] https://obamawhitehouse.archives.gov/the-press-office/2016/03/31/fact-sheet-transparency-us-highly-enriched-uranium-inventory

about 85 percent of its uranium requirements came from one source -- the Shinkolobwe vein in the Congo. U.S. production of uranium took off in the 1950s and, at its peak, constituted 45 percent of global production.[12]

Significant U.S. production of uranium ore coincided with government programs to encourage domestic uranium production with guaranteed prices and other incentives, setting up a uranium "rush" in the western states of Colorado, New Mexico, Utah, and Wyoming. By 1959, the US Atomic Energy Commission (AEC) began phasing out foreign uranium purchases, ending them in 1966. At the same time, the AEC embargoed enrichment of foreign-sourced uranium until 1984. It took forty years for foreign-sourced uranium to grow from ten percent of U.S. utilities' consumption to more than 90 percent. The United States has also recovered uranium from phosphoric acid, but only in years when uranium prices made such extraction economically viable.

The relative cost of domestic and foreign sources of uranium is a crucial factor in domestic US. production. When foreign uranium was phased back into the U.S. market, domestic production dropped off precipitously. Uranium traded at rock-bottom prices ($8-12/lb U3O8) from 1989 to 1995 and again from 1997 to 2003 (dropping to $7/lb in 2001). Although uranium prices have somewhat recovered (now at $24.51/lb U3O8, roughly the price of lobster), U.S. production has not. It is no surprise that the uranium that U.S. utilities purchased from domestic producers in 2018 had an average weighted price of $46.59 per pound of U3O8; from U.S. brokers, $52.51; and from foreign suppliers, $39.82.[13]

Although uranium may be strategic to the United States, it might not be "critical" as far as supply restrictions are concerned. The National Academy of Sciences 2008 report, *Minerals, Critical Minerals, and the U.S. Economy* defined critical minerals as minerals both "essential in use… and subject to supply restriction." The report further emphasizes the importance of "differentiating between the ideas that a mineral can be important, fundamental, or essential for many purposes, but may not be critical." The report specifically cited uranium among examples of minerals that, while essential in use, are not subject to sufficient supply concerns to be classified as critical.[14]

The key issue is availability -- whether geologic, economic, technical, political or social. Uranium is more abundant than tin, but less common than lead, zinc, copper or nickel. In some respects, geologic and economic availability are linked: resources are grouped according to the economic significance of deposits.[15] Supply is therefore somewhat expandable, depending on

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[12] See Squassoni, et al, *Governing Uranium in the United States*, (Washington DC: Center for Strategic & International Studies, 2014) https://csis-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/140228_Squassoni_GoverningUranium_WEB.pdf.

[13] https://www.eia.gov/uranium/marketing/html/table1.php

[14] https://www.nap.edu/catalog/12034/minerals-critical-minerals-and-the-us-economy

[15] See Uranium 2018: Resources, Production and Demand, (Paris and Vienna: Nuclear Energy Agency and International Atomic Energy Agency) 2018, available online at:

the how well costs can be recovered. For example, the volume of uranium estimated to be recoverable from seawater is more than 4 billion metric tons, or 500 times current reserves on land. However, the price of uranium extraction from seawater currently hovers around $400/lb. [16] Technical factors, particularly in the case of seawater extraction, can affect the calculation.

Political and social factors also play a role. For example, experts estimate reserves of uranium in the Antarctic, but it is not politically, socially or legally acceptable to mine there. The same has been true, thus far, of mining for uranium in the Grand Canyon. Recently, the U.S. Supreme Court upheld a ban on mining for uranium in the state of Virginia. Supply restrictions or disruptions can occur at home or abroad.

For foreign supply, alliances and governance matter. For example, the United States clearly faces different supply disruption risks for a mineral supplied primarily through Canada versus China. It is inconceivable that Canada or Australia would refuse to supply uranium to the United States. Not only does Canada supply the largest amount of uranium to the United States of any country, but Canada and Australia together hold approximately 2.3 million tons of identified reserves of uranium that can be produced for less than $130/kg.[17] While Russia has previously issued (so far empty) threats to restrict uranium exports to the United States, Russia represents only a fraction of U.S. uranium imports. U.S. allies could easily fill the gap, and U.S. production could also be ramped up. While only four U.S. in-situ leach plants were operating in the first quarter of 2019, many more mills, in-situ leach plants, and other facilities in the United States are on standby, or partially permitted and licensed.[18] According to industry analysis, the United States currently has the capacity to produce 25 million pounds of uranium oxide a year, over half of U.S. commercial fuel purchases in 2018.[19]

Supply disruptions can also be mitigated by stockpiling. Compared to oil or natural gas, uranium supplies are much less susceptible to disruption.[20] The Energy Information Administration reported that owners and operators of U.S. nuclear power plants held over 111 million pounds of uranium in inventory at the end of 2018. U.S. brokers and traders held an additional 10 million pounds of uranium in inventory, and U.S. converters, enrichers, fabricators, and producers held another 9 million pounds.[21]

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http://www.oecd-nea.org/ndd/pubs/2018/7413-uranium-2018.pdf. See also Allison M. Macfarlane and Marvin Miller, "Nuclear Energy and Uranium Resources," *Elements,* Volume 3, pp. 185-192, June 2007

[16] https://www.newsdeeply.com/oceans/articles/2018/06/28/the-nuclear-option-technology-to-extract-uranium-from-the-sea-advances

[17] https://www.eia.gov/uranium/marketing/pdf/umar2018.pdf; http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx

[18] https://www.eia.gov/uranium/production/quarterly/pdf/qupd.pdf

[19] http://www.i2massociates.com/downloads/EMDUraniumNuclearMineralsandREECommitteeAnnualReport-2019.pdf

[20] https://carnegieendowment.org/files/nuclear_energy_rebirth_resuscitation.pdf

[21] https://www.eia.gov/uranium/marketing/pdf/umar2018.pdf

Uranium may be a strategic fuel but its supply is also highly secure and stable. While the United States currently imports most of the uranium used as fuel for energy generation, these imports come largely from countries with low governance risk. Additionally, two of the three largest uranium producers in the world, Canada and Australia, are close strategic partners. The United States can supplement supply with considerable inventories held by converters, utilities and the Department of Energy, ramp up production, and if absolutely necessary, recycle spent fuel to extract uranium.

Unintended Consequences of Applying New Policy Goals to Uranium

One of the aims of the Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals is to spark new domestic production of critical minerals. EO 13817 calls for policies to streamline leasing and permitting processes to expedite exploration, production, processing, reprocessing, recycling, and domestic refining of critical minerals. A recent example regarding uranium is the petition by Energy Fuels Resources to overturn a 2012 decision by the Department of Interior to block uranium mining in the Grand Canyon. Energy Fuels Resources cited a serious crisis "because the vast majority of the uranium used in the US is imported." Reportedly, the petition asked the U.S. government to "buy its uranium exclusively from domestic producers and to set a quota guaranteeing US companies 25% of the market."[22] A ruling is expected in the coming weeks. Overall, a 25% quota for domestic production of uranium could increase fuel costs for some U.S. nuclear power plants, potentially pushing their operations into uneconomic territory. Talk of quotas for U.S. domestic production are reportedly part of President Trump's discussions with Canadian Prime Minister Justin Trudeau regarding import tariffs.[23]

If the aim of more domestic production is to actually fuel U.S. nuclear power plants with domestically sourced uranium, then US nuclear exports -- whether yellowcake, conversion services, enrichment services, or reactor components and reactors -- could suffer. This could have the unintended consequence of lifting nonproliferation encumbrances. At present, recipients of U.S. nuclear cooperation are required to adhere to a host of nonproliferation, safety and security measures outlined in Section 123 of the Atomic Energy Act. A policy that seeks to ensure that U.S. reactors are fueled with U.S. uranium rather than foreign uranium could have the unintended consequence of diminishing U.S. exports of uranium to foreign countries and thus diminishing the nonproliferation leadership of the United States.

Beyond exploration and production, the potential for reprocessing or recycling of fuel to recover uranium would be a negative development for nuclear nonproliferation. Nuclear fuel cycle back-end operations are restricted by established, long-standing policies of refraining from reprocessing of nuclear spent fuel on the basis of their significant proliferation risks. Policy

[22] https://www.cnn.com/2019/06/12/politics/grand-canyon-uranium-mining/index.html

[23] Jessica Sondgeroth, "Trump, Trudeau Talk Uranium," Nuclear Intelligence Weekly, Volume 13, Number 25, June 21, 2019, p. 2.

decisions to pursue such reprocessing to enhance domestic content of U.S. fuel would reverse decades of policy in an area critical to U.S. national security.

Conclusions

The supply of minerals, like energy, should be judged secure when it is reliable, adequate and affordable. Such secure supplies could be domestically or internationally sourced. There are few reputable analysts who would suggest that Canada or Australia might suddenly cut off supplies of uranium to the United States for political or economic reasons. Utilities in the United States purchased 42 percent of their uranium in 2018 from Canada and Australia, which are two of the top three producers of uranium; Australia has 30% of the known recoverable reserves.

As for other minerals, it may be possible to establish and maintain stockpiles to enhance reliability, particularly when quantities may not be very large. By focusing on vulnerability to foreign suppliers, the Trump administration's policy fails to consider that domestic supply can easily be as unreliable, inadequate and expensive as foreign supply. A simplistic focus on enhancing domestic sources misses these important characteristics of secure supply.

Uranium is a strategic resource but does not belong on the Critical Minerals List. Uranium meets none of the criteria for a critical mineral as defined by Executive Order 13817. It is not a non-fuel mineral, its supply chain is not vulnerable to disruption, and it does not serve "an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or national security."

If the Trump administration is concerned about non-fuel uses of uranium (excluding nuclear weapons), which are very small in scope and volume compared to fuel uses, the potential vulnerability to supply disruption argument would not merit keeping uranium on the Critical Minerals List. For military and defense purposes, U.S. production and DoE stockpiles should suffice.

Lastly, some of the policy prescriptions that would apply to uranium as a critical mineral could have unintended adverse impacts. US nuclear exports -- whether yellowcake, conversion services, enrichment services, or reactor components and reactors -- all carry with them nonproliferation encumbrances. In short, anything that originates or passes through the United States that is exported to a foreign country under the auspices of a nuclear cooperation agreement requires the recipient to adhere to a host of nonproliferation, safety and security measures outlined in Section 123 of the Atomic Energy Act. A policy that seeks to ensure that U.S. reactors are fueled with U.S. uranium rather than foreign uranium could have the unintended consequence of diminishing U.S. exports of uranium to foreign countries and thus diminish the nonproliferation leadership of the United States. A policy that creates a quota for domestic production may increase the price of fuel for U.S. nuclear power plants in an increasingly competitive environment for nuclear energy. And lastly, a policy that promotes reprocessing or recycling of fuel to increase the domestic content of U.S. uranium could harm U.S. national security more than it would help it by damaging U.S. nonproliferation leadership.