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The Front End of the Nuclear Fuel Cycle: Current Issues

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SUMMARY

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The Front End of the Nuclear Fuel Cycle: Current Issues

Nuclear power contributes roughly 20% of the electrical generation in the United States. Uranium is the fundamental element in fuel used for nuclear power production. The *nuclear fuel cycle* is the cradle-to-grave life cycle from extracting uranium ore from the earth through power production in a nuclear reactor to permanent disposal of the resulting spent nuclear fuel.

The *front end* of the nuclear fuel cycle considers the portion of the nuclear fuel cycle leading up to electrical power production in a nuclear reactor. The front end of the nuclear fuel cycle has four stages: mining and milling, conversion, enrichment, and fabrication. *Mining and milling* is the process of removing uranium ore from the earth and physically and chemically processing the ore to develop "yellowcake" uranium concentrate. Uranium *conversion* produces uranium hexafluoride, a gaseous form of uranium, from uranium concentrate. Uranium *enrichment* physically separates and concentrates the fissile isotope U-235. The enriched uranium used in nuclear power reactors is approximately 3%-5% U-235, while weapons-grade enriched uranium is greater than 90% U-235. Nuclear fuel *fabrication* involves manufacturing enriched uranium fuel rods and assemblies highly specific to a nuclear power reactor.

Historically, the Atomic Energy Commission (AEC), a predecessor federal agency to the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC), promoted uranium production through federal procurement contracts between 1947 and 1971. Since the late 1980s, U.S. nuclear utilities and reactor operators have purchased increasingly more foreign-origin uranium for reactor fuel than domestically produced uranium. In 1987, about half of uranium used in domestic nuclear reactors was foreign origin. By 2018, however, 93% of uranium used in U.S. nuclear reactors was foreign origin. No uranium conversion facilities currently operate in the United States. There is one operational U.S. commercial uranium enrichment facility that has the capacity to enrich approximately one-third of the country's annual reactor requirements. In additional to newly mined uranium, U.S. nuclear power reactors also rely on secondary sources of uranium materials. These sources include federal and commercial stockpiles, re-enrichment of depleted uranium, excess feed from underfeeding during commercial enrichment, and downblending of higher enriched uranium.

The global uranium market operates with multiple industries exchanging uranium products and services through separate, non-direct, and interrelated markets. Producers, suppliers, and utilities buy, sell, store, and transfer uranium materials. Nuclear utilities and reactor operators diversify fuel sources among primary and secondary supply and may acquire uranium from multiple domestic and foreign suppliers and servicers. For example, a nuclear power utility in the United States may purchase uranium concentrate that has been mined and milled in Australia, converted in France, enriched in Germany, and fabricated into fuel in the United States.

On January 16, 2018, two domestic uranium producers—representatives from the uranium mining/milling industry—petitioned the U.S. Department of Commerce to conduct a Section 232 investigation pursuant to the Trade Expansion Act of 1962 (19 U.S.C. §1862) to examine whether U.S. uranium imports pose a threat to national security. The President has until July 13, 2019, to decide if he concurs with the findings and determine what import actions to levy, if any.

The Section 232 uranium investigation into uranium imports has started a debate among domestic uranium producers and nuclear utilities and organizations operating nuclear fuel facilities. Uranium producers assert that low production of domestically sourced uranium concentrate poses a national security risk as fuel supplies are dependent on imported material. Nuclear utilities and reactor operators assert that increased fuel costs from trade restrictions would increase their financial burdens, leading to the premature shutdown of economically marginal nuclear power plants. Trade actions may have direct and indirect local, regional, and national economic impacts. Congress may examine the current status of domestic uranium supply and the long-term viability of these industries.

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Introduction

The United States has more nuclear power reactors than any country worldwide. The 98 operable nuclear generating units provide approximately 20% of the electrical generation in the United States.[1] Uranium is the fundamental element used to fuel nuclear power production. The *front end of the nuclear fuel cycle* comprises the industrial stages starting with uranium extraction from the earth and ending with power production in a nuclear reactor. Congressional interest in the front end of the nuclear fuel cycle is associated with many factors, including (1) domestic uranium production and supply, (2) concerns about increasing reliance on uranium imports, and (3) the economic viability of U.S. nuclear power reactors.

Historically, the U.S. Atomic Energy Commission, a predecessor federal agency to the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC), promoted uranium production in the United States through federal procurement contracts between 1947 and 1971.[2] The majority of domestic uranium concentrate production prior to 1971 supported the development of nuclear weapons and naval propulsion reactors. After 1971, uranium mill operators produced uranium concentrate primarily for the use in commercial nuclear power reactors.

By the late 1980s, nuclear utilities and reactor operators in the United States purchased more uranium from foreign suppliers than from domestic producers.[3] By 2017, 93% of the uranium purchased by U.S. nuclear utilities and reactor operators originated in a foreign country. Nuclear utilities and reactor operators diversify uranium supplies among multiple domestic and foreign sources intending to minimize fuel costs. For example, a nuclear utility in the United States may purchase uranium concentrate that has been mined and milled in Australia, converted in France, enriched in Germany, and fabricated into fuel in the United States.

Examination of the current status of the front end of the nuclear fuel cycle highlights broad policy questions about the federal government's role in sustaining or promoting nuclear fuel production in the United States. This report describes the front end of the nuclear fuel cycle and the global uranium marketplace, analyzes domestic sources and imports of various types of uranium materials involved in the fuel cycle, and provides a discussion about the current issues. The "back end" of the nuclear fuel cycle comprises the storage of spent nuclear fuel after it is discharged from a nuclear reactor. However, issues associated with spent nuclear fuel storage and disposal are not discussed in this report. This report does not discuss potential environmental, public health, and proliferation issues associated with the front end of the nuclear fuel cycle.

Front End of the Nuclear Fuel Cycle

The front end of the nuclear fuel cycle is composed of four stages:

[1] U.S. Energy Information Administration (EIA), *Monthly Energy Review—December 2018*, DOE/EIA-0035 (2018/12), p. 157.

[2] DOE, Office of Environmental Management, *Linking Legacies, Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences*, January 1997, p. 51.

[3] EIA, *Monthly Energy Review—May 2019*, Figure 8.2: Production and Trade, 1949-2018, p. 148, https://www.eia.gov/totalenergy/data/monthly/pdf/sec8_4.pdf.

1. Uranium *mining and milling* is the process of removing uranium ore from the earth and physically and chemically processing the ore to develop "yellowcake" uranium concentrate.
2. Uranium *conversion* produces uranium hexafluoride (UF_6), a gaseous form of uranium, from solid uranium concentrate.
3. Uranium *enrichment* separates and concentrates the fissile isotope U-235[4] in the gaseous UF_6 form to produce enriched uranium capable of sustaining a nuclear chain reaction in a commercial nuclear power reactor.[5]
4. Uranium fuel *fabrication* involves producing uranium oxide pellets, which are subsequently loaded into reactor-specific fuel rods and assemblies, which in turn are loaded into a nuclear power reactor.

Primary Supply

The nuclear fuel produced from processing newly mined uranium ore through fuel fabrication is referred to as primary supply. The stages from uranium mining through uranium fuel fabrication are described in the following sections.

Stage 1: Mining and Milling—Production of Uranium Concentrate

The front end of the nuclear fuel cycle begins with mining uranium ore from the earth through conventional (surface mining, open pits, underground) or non-conventional, *in-situ* recovery (ISR) methods. The type of extraction method employed depends on geology, ore body concentration, and economics. The majority of uranium resources in the United States are located in geological deposits in the Colorado plateau, Texas gulf coast region, and Wyoming basins.[6] The United States has a relatively low quality and quantity[7] of uranium reserves compared to the leading uranium producing countries. For example, the Nuclear Energy Agency and the International Atomic Energy Agency rank the United States reasonably assured uranium resources as 12th worldwide.[8]

Uranium *milling* involves physical and chemical processing of uranium ore to generate uranium concentrate (U_3O_8), commonly called "yellowcake" uranium. Uranium milling operations crush and grind the mined ore, which is chemically dissolved with acid or alkaline solutions and subsequently concentrated.[9] Milling operations produce a large quantity of waste material, called

[4] Uranium is found naturally on earth with approximately 0.71% of the isotope with an atomic weight of 235 (U-235) and more than 99% of the isotope with an atomic weight of 238 (U-238). Commercial nuclear power plants in the United States require fuel with a U-235 concentration of 3-5% U-235, which is necessary to sustain a nuclear reaction (i.e. "fissile").

[5] Low-enriched uranium is uranium with an isotopic composition of U-235 above natural uranium and below 20%. U-235 composition between 3%-5% is necessary to fuel today's commercial light-water reactors. Highly enriched uranium is uranium with an isotopic composition of U-235 that is 20% of greater. See International Atomic Energy Agency (IAEA), "IAEA Safeguards Glossary," https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf.

[6] International Uranium Resources Evaluation Project, *World Uranium, Geology and Resource Potential*, 1980, p. 378.

[7] The quality and quantity of uranium resources refers to uranium deposits with a relatively high ore grade and total mass.

[8] The five countries with the highest total reasonably assured resources are Australia, Canada, Kazakhstan, Namibia, and Niger. Nuclear Energy Agency and IAEA, *Uranium 2018: Resources, Production and Demand* ("The Red Book"), December 2018, p. 26.

[9] See NRC, *Conventional Uranium Mills*, May 15, 2017, https://www.nrc.gov/materials/uranium-recovery/extraction-methods/conventional-mills.html.

tailings, relative to the amount of uranium concentrate produced. NRC estimates that 2.4 pounds of yellowcake uranium oxide is produced from 2,000 pounds of uranium ore.[10] The tailings generated by uranium milling operations prior to the 1970s were largely abandoned, exposing radioactive sand-like particles to be dispersed into the air, surface, and groundwater by natural erosion and human disturbances. The enactment of the Uranium Mill Tailings Radiation Control Act (P.L. 95-604) authorized a remedial action program for cleanup of abandoned mill tailings prior to 1978 and authorized a regulatory framework to manage tailings generated at sites operating after 1978. In the United States, ISR methods have replaced conventional mining and milling by pumping acid or alkaline solutions through an underground ore body. After uranium in the ore is dissolved in solution, it is pumped to the surface and processed to produce uranium concentrate.

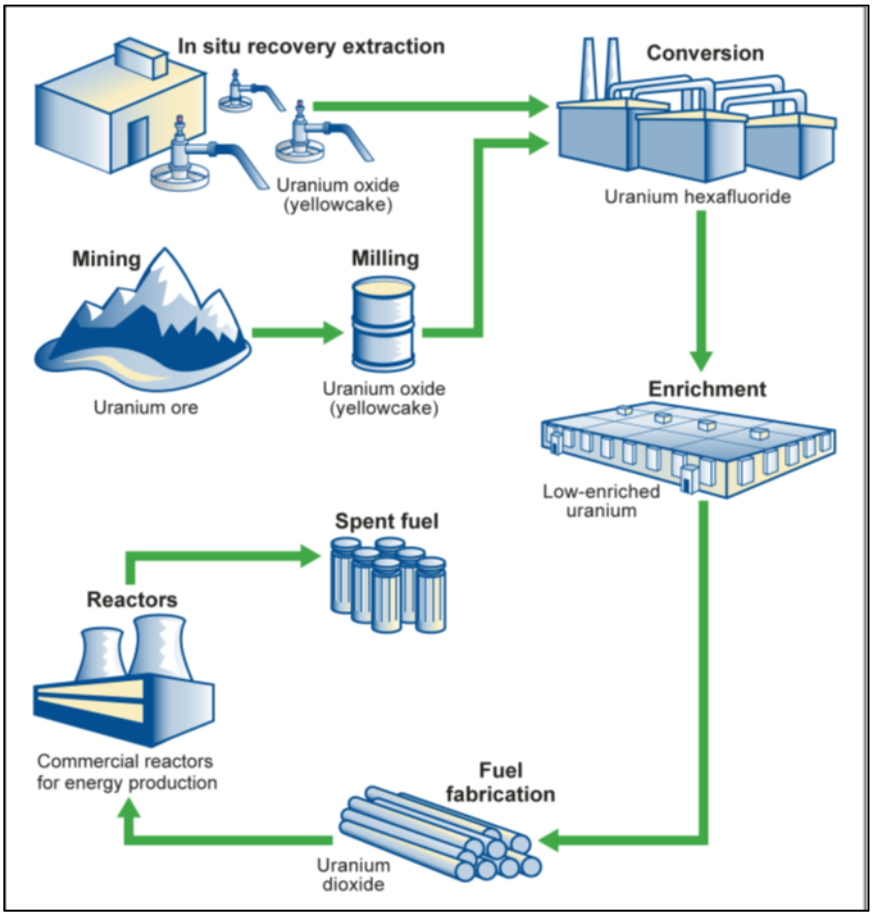
In the first quarter of 2019, five ISR facilities are operating in the United States—all in Wyoming—with approximately 11.2 million pounds of annual production capacity. One conventional uranium mill, located in Utah, is in operation with an annual capacity of 6 million pounds of ore per day.[11] Additionally, there are 13 million pounds of annual production capacity at 11 ISR operations that are permitted and licensed, partially permitted and licensed, developing, or on standby.[12]

[10] See NRC, *Final Generic Environmental Impact Statement on Uranium Milling*, NUREG-0706, September 1980, pp. 3-14, 15.

[11] The EIA reports total operational capacity differently for conventional uranium mills and ISR facilities as short tons and pounds of U_3O_8, respectively. Conventional uranium mills process ore that has been physically mined, and the ore grades and amount of uranium concentrate produced may not be precisely known until processing. For ISR operations, the uranium concentrate produced will be proportional to the concentration of dissolved uranium in the recovered solution. EIA, *Domestic Uranium Production Report—Quarterly*, Table 3 and Table 4, May 2019.

[12] EIA, *Domestic Uranium Production Report—Quarterly*, Table 4, May 2019.

Figure 1. Nuclear Fuel Cycle



Source: U.S. Government Accountability Office, *Nuclear Weapons, NNSA Should Clarify Long-Term Uranium Enrichment Mission Needs and Improve Technology Cost Estimates*, GAO-18-126, February 2018.

Notes: This report does not discuss issues with the storage of spent nuclear fuel after it is discharged from a nuclear reactor.

Stage 2: Conversion—Production of Uranium Hexafluoride

Uranium concentrate is shipped to a uranium *conversion* facility where UF_6 is chemically produced. At room temperature, UF_6 is a solid and transforms to a gas at higher temperatures. UF_6 is described as "natural," as the isotopic composition has not been altered relative to the composition that exists in nature. According to the World Nuclear Association, there are six uranium conversion plants worldwide.[13] The Honeywell plant in Metropolis, IL, is the only uranium conversion facility in the United States. It has not produced UF_6 since November 2017.[14]

[13] World Nuclear Association, *Conversion and Deconversion*, updated January 2019, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/conversion-and-deconversion.aspx.

[14] NRC, *Honeywell Metropolis Works—Licensee Performance Review of Licensed Activities (Nuclear Regulatory Commission Inspection Report 40-3392/2018-001)*, March 2, 2018.

Stage 3: Enrichment—Production of Enriched Uranium

After uranium conversion, the UF_6 is feed material for *uranium enrichment*. Natural uranium has an isotopic composition of approximately 0.71% U-235, the fissile isotope of uranium.[15] Civilian nuclear power fuel is generally enriched to 3%-5% U-235.[16] Uranium enrichment in the United States was largely performed using a gaseous diffusion technology until 2013. Currently, one uranium enrichment plant operates in the United States that employs gas centrifuge technology. The gas centrifuge technology is described below.

Inflow UF_6 gas—referred to as the *feed*—enters a gas centrifuge. The centrifuge spins at high speeds, and centrifugal forces drive the slightly more massive U-238 isotopes outwards, while less massive U-235 isotopes concentrate near the center of the centrifuge. The process repeats many times in a cascade of centrifuges, gradually increasing the isotopic composition of U-235 from 0.71% to 3%-5%. During this process, the chemical composition remains as UF_6, while the isotopic composition of UF_6 has been modified. The product stream is *enriched uranium hexafluoride* ($enUF_6$), and the waste stream—called the tails—is *depleted uranium*.

The greater the difference in the isotopic composition of U-235 in the product and tails, the greater the energy requirements. *Separative work units* describe the energy required to enrich a given feed quantity to a given assay. Uranium enrichment yields a relatively higher mass of depleted uranium as the enriched uranium product.[17]

Stage 4: Fabrication—Production of Uranium Oxide, Fuel Rods, and Assemblies

The final step in producing usable nuclear fuel involves *fuel fabrication*. At fabrication plants, enriched uranium is converted to uranium oxide powder and subsequently formed into small ceramic pellets. The pellets are loaded into cylindrical fuel rods and then combined to form fuel assemblies specific to a particular reactor. The fuel assemblies are loaded into the nuclear reactor for power production. The precise enrichment level and types of fuel rods and assemblies are specific to each reactor.

Secondary Supply

Secondary supplies describe uranium materials that may not have been directly processed through the front end of the nuclear fuel cycle. Secondary supply may describe excess uranium from underfeeding during commercial enrichment, uranium materials held in commercial inventories, uranium held in the federal government's excess uranium inventory, and the downblending of higher enriched uranium.[18] According to DOE, secondary sources of uranium produced from re-

[15] The nucleus of an element is composed of protons and neutrons. An isotope is an element consisting of nuclei with the same number of protons but differing numbers of neutrons. The total number of protons is the *atomic number*. The total number of protons and neutrons is the *atomic mass number*. The *relative atomic mass* is the mean of the atomic mass numbers and relative abundance for all isotopes of an element. The enrichment level of uranium isotopes is described by percent U-235, which describes the relative abundance of U-235 atoms in a sample. For practical nuclear fuel cycle applications, this percentage is commonly called the uranium *assay*.

[16] Uranium enriched for civilian nuclear power production is commonly referred to low-enriched uranium.

[17] As of August 2017, NRC estimated that DOE stored approximately 750,000 metric tons of depleted uranium. NRC, *Background Information on Depleted Uranium*, last updated August 9, 2017, https://www.nrc.gov/waste/llw-disposal/llw-pa/uw-streams/bg-info-du.html.

[18] DOE, *Analysis of Potential Impacts of Uranium Transfers on the Domestic Uranium Mining, Conversion, and*

enrichment of depleted uranium and underfeeding represent the two largest sources of secondary supply in the market.[19] A uranium market analyst estimated that all secondary supplies account for more than a quarter of total annual world uranium supply (48 million pounds U_3O_8 equivalent[20]) as of December 2018.[21] The relative contribution of secondary uranium supplies may vary from year to year.

Underfeeding

Uranium enrichment inherently involves a trade-off between energy requirements and quantity of product and tails produced. Enrichment operators aim to balance these requirements as the optimal tails assay. Under certain conditions, enrichment operators elect to *underfeed*, which generates tails with a lower assay relative to the optimal tails assay. Underfeeding allows the enrichment operator to supply the enriched uranium product at the assay desired, produce lower quantities of tails for storage and disposal, and use relatively less feed material. The trade-off is the higher energy requirement per enriched product. The excess feed material not enriched as a result of underfeeding is considered a secondary supply.

Traders and Brokers

Uranium traders and brokers buy, sell, and store various types of uranium materials and have no direct operational role in producing or consuming nuclear fuel cycle material. The decision to buy, hold, and sell uranium materials is dependent on market conditions. For example, in 2014 the Senate Committee on Homeland Security and Governmental Affairs examined the activities of banks and bank holding companies in physical markets for commodities. Included in that investigation was an examination of Goldman Sachs involvement with buying and selling physical uranium products. Goldman Sachs described its activities in the uranium market as "buying uranium from mining companies, storing it, and providing the uranium to utilities when they wanted to process more fuel for their nuclear power plants."[22] Goldman's physical uranium inventory valuation peaked in 2013 at $242 million, and the company planned on exiting the market by 2018 when their contracts with utilities had ended.[23] The current status of Goldman's holdings are not publicly known, as uranium sales contracts are privately negotiated. The U.S. Energy Information Administration (EIA) provides a list of uranium sellers to owners and operators of U.S. civilian nuclear power reactors, which may include companies involved with uranium operations at various stages of the front end of the nuclear fuel cycle.[24]

Enrichment Industries, April 26, 2017, p. 45.

[19] DOE, *Secretarial Determination for the Sale or Transfer of Uranium*, April 26, 2017, https://www.energy.gov/sites/prod/files/2017/04/f34/2017%20Secretarial%20Determination%20and%20Analysis%20Public.pdf.

[20] U_3O_8 equivalents—U_3O_8(eq)—is a unit of measurement used to normalize the components of uranium concentrate, uranium hexafluoride, and enriched uranium.

[21] See "UxC's Nick Carter Predicts 'Gradual Upward Movement' of Uranium Price," *Northern Miner*, January 26, 2019.

[22] U.S. Congress, Senate Committee on Homeland Security and Governmental Affairs, Permanent Subcommittee on Investigations, *Wall Street Bank Involvement With Physical Commodities*, 114th Cong., December 5, 2014, p. 132.

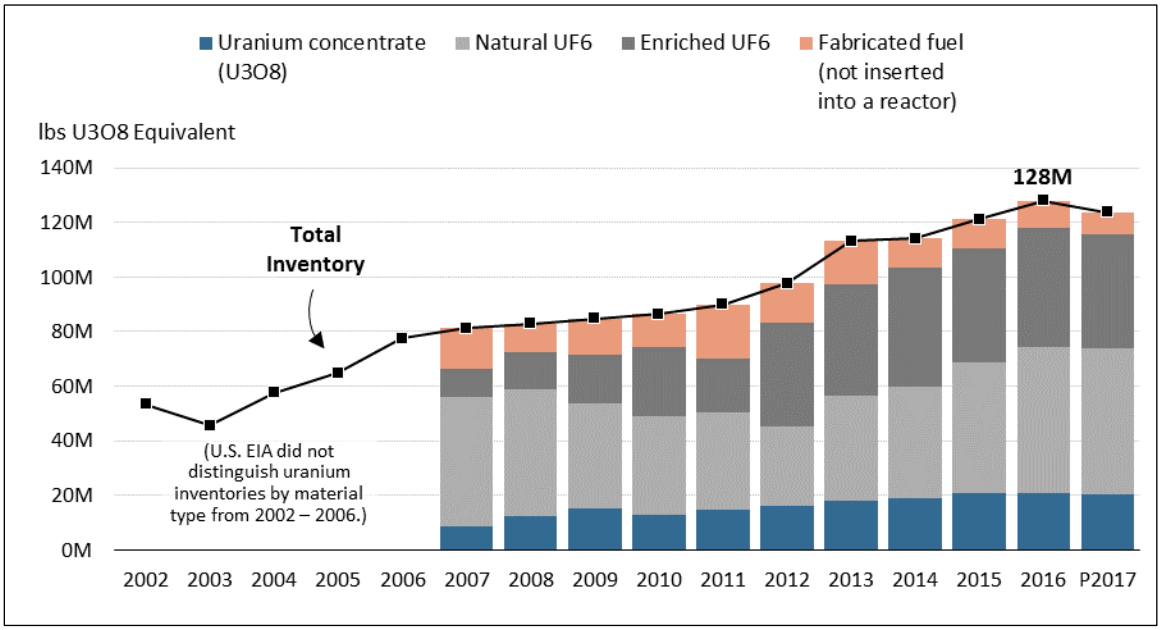
[23] See Senate Committee on Homeland Security and Governmental Affairs, Permanent Subcommittee on Investigations, *Wall Street Bank Involvement With Physical Commodities*, pp. 117 and 131.

[24] EIA, *Uranium Marketing Annual Report*, Table 24: Uranium sellers to owners and operators of U.S. civilian nuclear power reactors, 2015-2017, May 31, 2018, https://www.eia.gov/uranium/marketing/html/table24.php.

Commercial Inventories

Nuclear utilities and reactor operators stockpile uranium inventories of various types of uranium materials. The primary reasons to maintain stockpiles are economic considerations and insulation of their operations from potential supply chain disruptions. According to EIA, total uranium inventories for owners and operators of U.S. civilian nuclear power reactors more than doubled from 2002 to 2016 (**Figure 2**). EIA tracked inventory quantities of specific uranium materials from 2007 to 2016. During that time, owners and operators of U.S. civilian nuclear power reactors increased inventories of uranium concentrate and enriched UF_6 by the largest relative margin. As of 2016, EIA reported that the total uranium inventory for U.S. utilities was 128 million pounds of U_3O_8(eq).[25]

Figure 2. Uranium Inventories by Type for Owners and Operators of U.S. Civilian Nuclear Power Reactors



Source: Created by CRS. Information from U.S. Energy Information Administration (EIA), *2005 Uranium Marketing Annual Report*, May 11, 2006, Table 22; EIA, *2008 Uranium Marketing Annual Report*, May 26, 2009, Table 22; EIA, *2011 Uranium Marketing Annual Report*, May 2015, p. 37; EIA, *2013 Uranium Marketing Annual Report*, May 2014, p. 55; EIA, *2017 Uranium Marketing Annual Report*, May 2018, p. 56.

Notes: EIA defines "P" as preliminary data for 2017. In the legend, "Natural UF6" refers to natural uranium hexafluoride and "Enriched UF6" refers to enriched uranium hexafluoride.

Excess Federal Uranium Inventory

DOE maintains inventories of uranium both essential to and excess to national security missions.[26] DOE maintains excess inventories of various types of uranium materials, which are

[25] EIA, *Uranium Marketing Annual Report*.

[26] Multiple offices within DOE coordinate the management of these materials, including the Office of Nuclear Energy, the Office of Environmental Management, and the National Nuclear Security Administration.

sold on commercial markets to support cleanup services for former federal uranium enrichment facilities.[27]

Some have expressed concern that DOE's uranium transfers are depressing uranium prices by introducing federal uranium materials into an already oversupplied market. In 2015, the House Oversight and Government Reform Subcommittee on the Interior examined the impact of the sales of DOE's excess uranium inventory.[28] The Government Accountability Office raised concerns about the transparency of methodology used to determine uranium transfer quantities and expressed legal concerns with some DOE uranium transfers from 2012 through 2013.[29] The Secretary of Energy determines whether transfers of uranium will adversely affect the domestic production uranium industry.[30] In FY2017, Secretary of Energy Rick Perry determined that natural uranium hexafluoride transfer of up to 1,200 metric tons (MT) of uranium per year would not cause adverse material impact on domestic uranium producers.[31]

Explanatory language in the conference report accompanying the Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019 (P.L. 115-244, H.Rept. 115-929) directs DOE to end the uranium transfers and explains that $60 million above the budget request is appropriated in lieu of anticipated profits from those transfers.[32] The DOE FY2020 budget request decreased funding requests for the Portsmouth cleanup by approximately $52 million, indicating that DOE intends to resume uranium transfers in FY2020.[33]

[27] For example, the Portsmouth Gaseous Diffusion Plant in Piketon, OH, which operated from 1954 to 2001, initially produced highly enriched uranium for nuclear weapons and naval propulsion and research as well as low-enriched uranium for commercial nuclear power reactors. The DOE Office of Environmental Management manages the decontamination and decommissioning of the site. DOE estimates decontamination and decommissioning of the Portsmouth plant will be completed by 2039-2041 with a life-cycle cost ranging from $17.5 billion to $18.5 billion. See DOE, *FY2019 Congressional Budget Request*, Environmental Management Volume 5, DOE/CF-0142, March 2018, pp. 77 and 110.

[28] U.S. Congress, House Committee on Oversight and Government Reform, Subcommittee on the Interior, *Examining the Department of Energy's Excess Uranium Management Plan*, 114th Cong., 1st sess., April 22, 2015, HRG-2015-CGR-0015.

[29] U.S. Government Accountability Office, *Department of Energy: Management of Excess Uranium*, GAO-15-475T, April 22, 2015.

[30] 42 U.S.C. §2297h-9(d).

[31] DOE, *Secretarial Determination for the Sale or Transfer of Uranium*.

[32] U.S. Congress, House Committee on Appropriations, *Energy and Water Development and Related Agencies for the Fiscal Year Ending September 30, 2019, and for Other Purposes*, 115th Cong., 2nd sess., H.Rept. 115-929 (Washington: GPO, 2018), p. 160. ("Portsmouth.—The conferees includes $60,000,000 above the budget request for Portsmouth cleanup, which is equivalent to the amount of proceeds that the Department planned to generate through bartering arrangements in order to fund additional cleanup in fiscal year 2019. The Department shall not barter, transfer, or sell uranium in order to generate additional funding for Portsmouth cleanup that is in excess of the amount of funding provided in this Act.")

[33] DOE, *FY2020 Congressional Budget Request, Environmental Management*, March 2019, p. 146, https://www.energy.gov/sites/prod/files/2019/04/f61/doe-fy2020-budget-volume-5_0.pdf. ("Decrease reflects an offset by the resumption of uranium transfers (barter) pending renewal of Secretarial Determination needed to continue deactivation of the second Process building (X333).")

Uranium for Defense and Other Purposes

Uranium is used in nondefense space missions, generation of medical isotopes, defense-related nuclear applications, and naval propulsion. Uranium with an assay of 20% or higher U-235 is referred to as highly enriched uranium (HEU), and weapons-grade HEU is greater than 90% U-235.

The United States no longer uses enriched uranium produced through the nuclear fuel cycle as HEU for U.S. nuclear weapons. The United States discontinued production of HEU for nuclear weapons by 1964 due to the buildup of sufficient defense stockpiles and ended all production of HEU by 1992. The U.S. Navy relies exclusively on federal stockpiles of HEU for nuclear-powered naval propulsion for all U.S. aircraft carriers and submarines.

In March 2016, the Obama Administration declassified the quantity of the federal stockpile of HEU overseen by DOE. As of September 2013, the Obama Administration reported that the United States had 585.6 MT of HEU, of which 499.4 MT was specifically allocated for "for national security or non-national security programs including nuclear weapons, naval propulsion, nuclear energy, and science."[34]

Global Uranium Market and Fuel Supply Chains

The uranium market operates with multiple industries exchanging uranium products and services through separate, non-direct, and interrelated markets. Producers, suppliers, and utilities buy, sell, store, and transfer uranium materials. For example, a contract may be established between a nuclear utility and a uranium producer for a given amount of uranium concentrate production over a certain number of years. The uranium producer generates uranium concentrate, which is shipped to a conversion facility. The utility contracts with a conversion facility to convert uranium concentrate to UF_6. Finally, the utility may arrange a contract for uranium enrichment services.

Uranium transactions occur through bilateral contractual agreements among buyers, sellers, and traders. Civilian nuclear power utilities purchase uranium through long-term multiyear contracts or through the spot market as a one-time purchase and delivery. For uranium materials delivered in 2017, roughly 86% were purchased through long-term contracts and about 14% through spot market purchases.[35]

In the United States, utilities may simultaneously arrange contracts with multiple uranium producers or suppliers for a given number of years. For example, a U.S. nuclear power utility may decide to engage with a uranium producer in Canada, a uranium conversion facility in the United States, a uranium enrichment facility in Germany, and a uranium fuel fabricator in the United States (**Figure 3**). That same utility may arrange another contract for uranium concentrate from Australia, uranium conversion in France, uranium enrichment in the Netherlands, and uranium fuel fabrication in the United States. At the same time, the utility may also decide to acquire uranium materials from a secondary supply source or through a trader or broker. Traders or brokers may not produce uranium products or services, but they buy, sell, and store materials to utilities and other suppliers. In this way, nuclear utilities and reactor operators may seek to diversify nuclear fuel sources between primary and secondary suppliers to avoid supply disruptions.

[34] The White House, "Fact Sheet: Transparency in the U.S. Highly Enriched Uranium Inventory," March 31, 2016, https://obamawhitehouse.archives.gov/the-press-office/2016/03/31/fact-sheet-transparency-us-highly-enriched-uranium-inventory.

[35] EIA, *Uranium Marketing Annual Report*, Table 7. pp. 1, 29.

Uranium Imports and Exports

The U.S. International Trade Commission (ITC) categorizes imports and exports by the Harmonized Tariff Schedule (HTS).[36] ITC reports uranium imports relevant to the nuclear fuel cycle in different HTS categories and subcategories (see **Table 1**). For this report, CRS provides data from only the top five importing or exporting countries from 1992 through January 2019. Other countries may have contributed lesser amounts of uranium imports or exports over that time period, but that data was not included in this report.

Table 1. Uranium Imports HTS Numbers

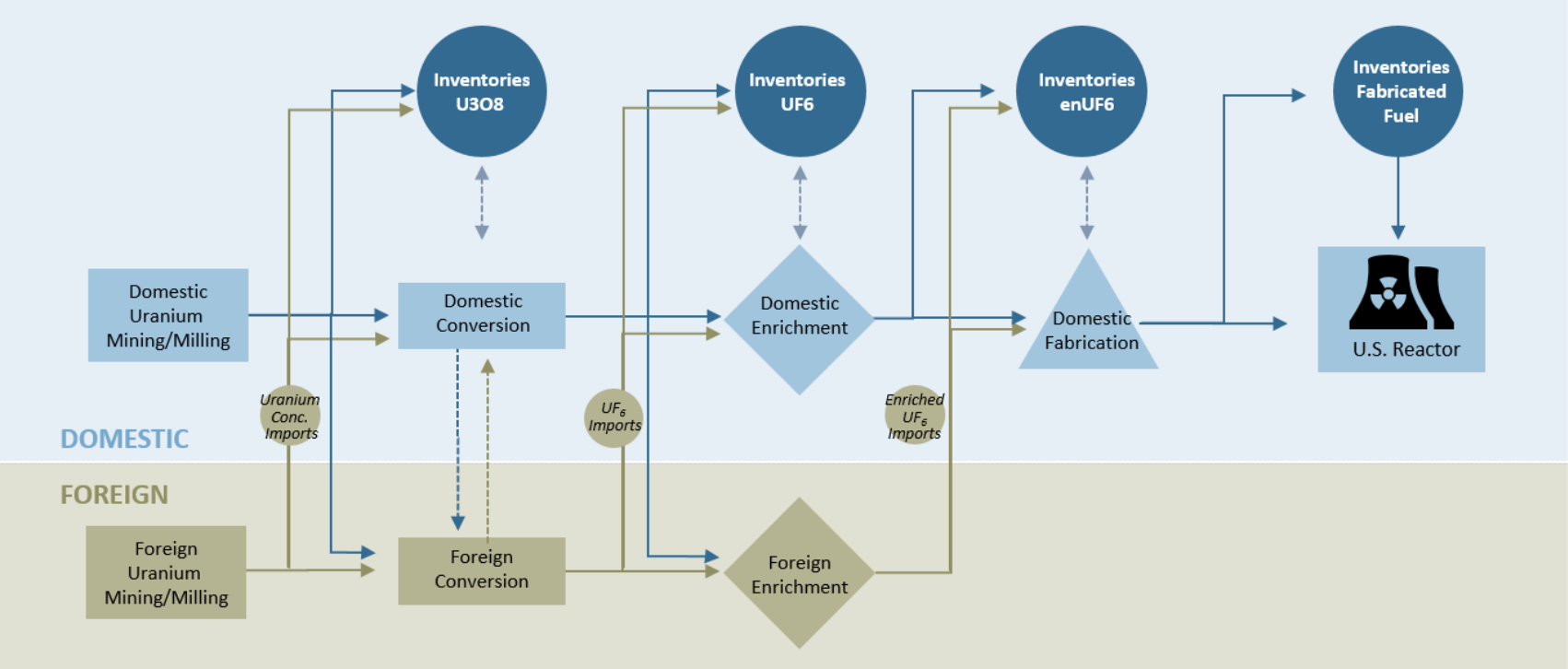
Uranium Import Type	Table Number	Harmonized Tariff Schedule Number	Full Description
Uranium Ores and Concentrates	Table 2	2612.10.00.00	Uranium ores and concentrates
Natural Uranium Oxide	Table 3	2844.10.20.10	Natural uranium and its compounds; alloys, ceramic-metal composites ("cermets"), ceramic products and mixtures containing natural uranium or natural uranium compounds: • Uranium compounds • Oxide
Natural Uranium Hexafluoride (UF_6)	Table 4	2844.10.20.25	Natural uranium and its compounds; alloys, ceramic-metal composites ("cermets"), ceramic products and mixtures containing natural uranium or natural uranium compounds: • Uranium compounds • Hexafluoride
Enriched Uranium Hexafluoride ($enUF_6$)	Table 7	2844.20.00.20	Uranium enriched in U-235 and its compounds; plutonium and its compounds; alloys, ceramic-metal composites ("cermets"), ceramic products and mixtures containing uranium enriched in U-235, plutonium or compounds of these products. • Fluorides

Source: U.S. International Trade Commission, *Harmonized Tariff Schedule of the United States (2018) Revision 14*, Chapter 26: Ores, Slag, and Ash, https://hts.usitc.gov/current. U.S. International Trade Commission, *Harmonized Tariff Schedule of the United States (2018) Revision 14*, Chapter 28: Inorganic Chemicals; Organic or Inorganic Compounds of Precious Metals, of Rare-earth Metals, of Radioactive Elements or of Isotopes, https://hts.usitc.gov/current.

Notes: HTS numbers describe relevant front-end of the nuclear fuel cycle uranium imports.

[36] ITC, *Purpose of the Harmonized Tariff Schedule*, https://www.usitc.gov/elearning/hts/menu/.

Figure 3. Nuclear Fuel Cycle: Import and Exports



Source: CRS generated a conceptual diagram depicting uranium material flows at the front end of the nuclear fuel cycle.

Notes: The figure shows a simplified version of the nuclear fuel supply chain for domestic nuclear power reactors.

Domestic and *foreign* are used here consistent with DOE's interpretations of the terms. *Domestic* refers to physical facilities operating within the United States regardless of a foreign corporation ownership. In some instances, domestic uranium producers, suppliers, enrichers, and utilities operating in the United States have foreign ownership or are subsidiaries of foreign corporations. The term *foreign* is used to describe any non-U.S.-based facility or material origin. Foreign inventories may exist in other countries but are not shown here.

Analysis of Uranium Supply to U.S. Nuclear Power Reactors

Since the late 1980s, U.S. nuclear utilities and reactor operators have purchased increasingly more foreign-origin uranium for reactor fuel than domestically produced uranium.[37] Historically, the Atomic Energy Commission, a predecessor federal agency to DOE and NRC, promoted uranium production through federal procurement contracts between 1947 and 1971.[38] After 1971, uranium mill operators produced uranium concentrate primarily for the production of civilian nuclear energy. In 1987, about half of uranium used in domestic nuclear reactors was foreign origin; by 2018, EIA reported 93% of uranium used in domestic nuclear reactors was foreign origin.

The DOE recognizes the term *domestic* as physical facilities operating within the United States regardless of a foreign corporation ownership.[39] Several domestic uranium producers, suppliers, enrichers, and utilities operating in the United States have foreign ownership or are subsidiaries of foreign corporations. On the other hand, DOE does not consider brokers and traders of already milled, converted, or enriched uranium as part of the domestic industry, as they are not associated with physical production of those materials. The term *foreign* is used to describe any non-U.S.-based facility or material origin.

The following sections describe domestic uranium sources and foreign imports by year and country associated with the front end of the nuclear fuel cycle. Uranium materials sourced from various countries may be associated with that country's natural resources, operational fuel cycle facilities, and trade agreements with the United States. For example, Australia, one of the largest exporters of uranium concentrate to the United States, has the largest reasonable assured uranium resources worldwide, but it does not have a commercial nuclear power plant in operation.[40] On the other hand, some overseas producers may not have the geological resources to mine and mill uranium concentrate, but they may operate conversion or enrichment operations.

Uranium Ores and Concentrates

Uranium extraction worldwide has shifted away from conventional (underground or surface mining) to unconventional (ISR) methods. In 2016, ISR facilities produced about half of the annual global uranium concentrate.[41] ISR methods are less capital-intensive operations relative to

[37] EIA, *Monthly Energy Review—May 2019*, Figure 8.2: Uranium Overview, https://www.eia.gov/totalenergy/data/monthly/pdf/sec8_4.pdf.

[38] DOE, Office of Environmental Management, *Linking Legacies, Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences*, January 1997. p. 51.

[39] See DOE, *Analysis of Potential Impacts of Uranium Transfers on the Domestic Uranium Mining, Conversion, and Enrichment Industries*, p. 20. ("DOE interprets the word 'domestic' to refer to activities taking place in the United States, regardless of whether the entity undertaking those activities is itself foreign. Hence, a facility operating in the United States would be part of 'domestic industry' even if the facility is owned by a foreign corporation. DOE believes that the phrase 'uranium mining, conversion or enrichment industry' includes only those activities concerned with the actual physical processes of mining, converting, and/or enriching uranium.")

[40] Nuclear Energy Agency and IAEA, *Uranium 2018*, p. 26.

[41] World Nuclear Association, *In Situ Leach Mining of Uranium*, October 2017, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium.aspx.

conventional mining methods, yet the uranium ore must be hosted within a geological formation suitable for extraction by ISR.

Preliminary data for domestic uranium concentrate production in the United States in 2018 totaled approximately 1.5 million pounds,[42] the lowest domestic uranium concentrate production since the early 1950s.[43] Domestic uranium concentrate production outlook remains low for 2019. EIA estimated the first quarter domestic production of uranium concentrate was 58,000 pounds, approximately four times lower than any reported quarter since 1996.[44]

Uranium ore and concentrates are imported into the United States from countries with considerable uranium production programs. According to the World Nuclear Association, the largest uranium producing countries in the world in 2017 were, in order of uranium concentrate production, Kazakhstan, Canada, Australia, Namibia, Niger, Russia, Uzbekistan, China, the United States, and Ukraine.[45]

Uranium concentrate imports are presented in **Table 2** and **Table 3**. As a practical matter, CRS combines "uranium ore and concentrates" (**Table 2**) and "natural uranium oxide" (**Table 3**) as similar materials produced from uranium mining and milling.[46] In 2018, the United States imported the largest quantities of uranium concentrate from Canada and Australia at 4.2 million kilograms (11 million pounds U_3O_8(eq)) and 1.1 million kilograms (2.9 million pounds U_3O_8(eq)), respectively.[47]

The United States does not currently have an operational uranium conversion facility to convert uranium concentrate to UF_6.[48] Consequently, uranium concentrate imported into the United States must be exported to a foreign country capable of conversion and enrichment services or stored in inventories.

[42] EIA, *Domestic Uranium Production Report—Quarterly*, Figure 1.

[43] EIA, *Monthly Energy Review—May 2019*, Table 8.2 Uranium Overview, https://www.eia.gov/totalenergy/data/monthly/pdf/sec8_4.pdf.

[44] EIA, *Domestic Uranium Production Report—Quarterly*, Table 1, https://www.eia.gov/uranium/production/quarterly/pdf/qupd_tbl1.pdf.

[45] World Nuclear Association, *World Uranium Mining Production*, updated March 2019, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx.

[46] CRS is uncertain how *uranium ores* and *concentrates* are defined by ITC, as "concentrate" is the physical and chemical product from "ore" processing. *Natural uranium oxide* is also used to describe uranium concentrate. For example, in some descriptions, the World Nuclear Association describes the product of uranium milling as "uranium oxide concentrate." World Nuclear Association, *Uranium Mining Overview*, February 2019, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx. Similar descriptions of "uranium oxide concentrate" have been used in other reports. See Nuclear Energy Agency and IAEA, *Uranium 2018*.

[47] CRS converted ITC uranium concentrate (kgU) to U_3O_8 equivalents by assuming 1 kg U_3O_8 (eq) = 0.848 kgU and 2.2 lbs. U_3O_8(eq) = 1 kg U_3O_8(eq). However, the subsequent data in **Table 2** through **Table 7** maintain units of kilograms as U to present the data as reported by the Census Bureau.

[48] Historically, several uranium conversion facilities operated in the United States. More recently, the facility in Metropolis, IL, owned and operated by Honeywell International, suspended operations in 2017.

Table 2. Annual U.S. Imports of Uranium Ores and Concentrates by Country

HTS 2612.10

Country	1992-2019 (January) PEAK YEAR OTHER YEARS	Imports in 2018 (kg)	Peak Year Imports (kg)	Total Imports 1992-2019 (January) (kg)
Australia		1,053,113	5,898,453	49,845,128
Namibia		166,058	2,187,298	14,252,373
Kazakhstan		0	1,934,508	11,013,935
Uzbekistan		0	1,032,019	3,037,092
Russia		0	251,171	846,093

Source: U.S. Census Bureau Trade Data. (U.S. Census Bureau does not recommend a formal way of citing data used from its website; see https://www.census.gov/about/policies/citation.html.)

Notes: Countries are shown by cumulative imports from 1992 to January 2019.

Table 3. Annual U.S. Imports of Natural Uranium Oxide by Country

HTS 2844.10.20.10

Country	1992-2019 (January) PEAK YEAR OTHER YEARS	Imports in 2018 (kg)	Peak Year Imports (kg)	Total Imports 1992-2019 (January) (kg)
Canada		4,228,409	6,395,213	78,716,952
Australia		0	4,372,159	31,664,943
South Africa		153,565	1,381,455	11,243,954
Uzbekistan		0	1,844,669	8,650,325
Kazakhstan		320,020	944,936	7,363,865

Source: U.S. Census Bureau Trade Data. (U.S. Census Bureau does not recommend a formal way of citing data used from its website; see https://www.census.gov/about/policies/citation.html)

Notes: Countries are shown by cumulative imports from 1992 to January 2019.

Uranium Hexafluoride

The production of UF_6 is the second stage of the front end of the nuclear fuel cycle. The United States currently has one commercial conversion facility, the Honeywell International plant in Metropolis, IL.[49] The facility temporarily suspended operations in 2018 due to "a worldwide oversupply of uranium hexafluoride" and is currently being maintained at a "ready-idle" status.[50] With the Honeywell facility on standby, the United States does not have a domestic uranium conversion facility in operation. The Honeywell facility in Metropolis continues to be operated by ConverDyn Corporation as a warehouse and international trading platform for UF_6 and uranium concentrate.[51] According to ConverDyn, 62 million pounds of UF_6 are stored at the facility as of 2018.[52] According to the World Nuclear Association, the majority of commercial uranium conversion capacity is located in Canada, China, France, Russia, and the United States.[53]

Since 1992, the United States' largest import source of UF_6 was Canada (137 million kg). The next highest country providing UF_6 imports to the United States over that time period was the United Kingdom (5.6 million kg) (**Table 4**).

The export trade data for UF_6 provides additional insight into the international flow of UF_6, which is feed material for commercial uranium enrichment. The ITC has two types of export classifications, *domestic exports* and *foreign exports*. These definitions are not the same as those interpreted by DOE described previously:

- *Domestic exports* are "goods that are grown, produced, or manufactured in the United States and commodities of foreign origin that have been changed in the United States, including changes made in a U.S. Foreign Trade Zone, from the form in which they were imported, or which have been enhanced in value by further processing or manufacturing in the United States" (**Table 5**).
- *Foreign exports* "(re-exports) consist of commodities of foreign origin that have previously been admitted to U.S. Foreign Trade Zones or entered the United States for consumption, including entry into a [U.S. Customs and Border Protection] bonded warehouse, and which, at the time of exportation, are in substantially the same condition as when imported" (**Table 6**).

[49] NRC, *Honeywell*, updated April 4, 2017, https://www.nrc.gov/info-finder/fc/honeywell-works-uranium-conv-il-lc.html.

[50] U.S. Nuclear Regulatory Commission, *Honeywell Metropolis Works—Licensee Performance Review of Licensed Activities (Nuclear Regulatory Commission Inspection Report 40-3392/2018-001)*, Adams Accession Number: ML18064A065, Atlanta, GA, March 2, 2018.

[51] See ConverDyn, *Comments on Section 232 National Security Investigation of Imports on Uranium 83 Fed. Reg. 35,204 (July 25, 2018)*, Docket ID BIS-2018-0011, September 24, 2018. According to comments by ConverDyn, "MTW [Metropolis Works] is currently the largest global trading platform for uranium. Uranium suppliers—both domestic and international—pay ConverDyn to store uranium at MTW prior to selling the material to third parties. MTW is an ideal place to store such materials because of its role as a primary supplier of conversion services, its accessibility to established uranium transportation networks, and the stable political and regulatory frameworks governing trade in nuclear materials here in the United States. Because MTW serves as a trading platform, suppliers may not know the identity of the eventual buyer, or whether the buyer is domestic or international, upon initial delivery to MTW. International suppliers therefore often do not know the identity of the ultimate buyer at the time of initial import into the United States."

[52] See ConverDyn, *Comments on Section 232 National Security Investigation*.

[53] World Nuclear Association, *Conversion and Deconversion*, 2019, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/conversion-and-deconversion.aspx.

The incidence of *domestic exports* may demonstrate domestic uranium concentrate that has undergone uranium conversion in the United States prior to export. Another explanation is that the incidence of *domestic exports* may indicate foreign mined and milled uranium concentrate imported into the United States that was converted and exported.

The incidence of *foreign exports* may indicate UF_6 imported into the United States that was re-exported for enrichment services in a foreign country. This interpretation is consistent with the comments provided by ConverDyn, which stated that Honeywell operates as a "global trading warehouse."[54] Since 2010, UF_6 foreign exports have totaled roughly 32 million kilograms to four countries: Russia, Germany, the Netherlands, and the United Kingdom.

Table 4. Annual U.S. Imports of Natural Uranium Hexafluoride (UF_6) by Country

HTS 2844.10.20.25

Country	1992-2019 (January) PEAK YEAR / OTHER YEARS	Imports in 2018 (kg)	Peak Year Imports (kg)	Total Imports 1992-2019 (January) (kg)
Canada		217	12,493,720	137,432,434
United Kingdom		0	3,250,128	5,583,099
Australia		0	457,172	821,149
South Africa		0	300,097	519,985
Germany		0	115,630	459,734

Source: U.S. Census Bureau Trade Data. U.S. Census Bureau does not recommend a formal way of citing data used from its website. See https://www.census.gov/about/policies/citation.html.

Notes: Countries are shown by cumulative imports from 1992 to January 2019. Imports from Australia, South Africa, and Germany are not in relatively high enough quantities to display on the figure.

Table 5. Annual U.S. "Domestic" Exports of Natural Uranium Hexafluoride (UF_6) by Country

HTS 2844.10.20

Country	1992-2019 (January) PEAK YEAR / OTHER YEARS	Exports in 2018 (kg)	Peak Year Exports (kg)	Total Exports 1992-2019 (January) (kg)
Netherlands		49,340	5,434,525	17,513,009
United Kingdom		0	2,550,280	11,998,839
Russia		78,284	2,589,205	7,165,895
France		0	1,487,524	4,394,351
Germany		390,386	657,849	3,541,880

[54] See ConverDyn, *Comments on Section 232 National Security Investigation*.

Source: U.S. Census Bureau Trade Data. U.S. Census Bureau does not recommend a formal way of citing data used from its website. See https://www.census.gov/about/policies/citation.html.

Notes: *Domestic exports* is defined as goods that are grown, produced, or manufactured in the United States and commodities of foreign origin that have been changed in the United States, including changes made in a U.S. Foreign Trade Zone, from the form in which they were imported or have been enhanced in value by further processing or manufacturing in the United States.

Countries are shown by cumulative imports from 1992 to January 2019.

Table 6. Annual U.S. "Foreign" Exports of Natural Uranium Hexafluoride (UF_6) by Country

HTS 2844.10.20

Country	1992-2019 (January) PEAK YEAR / OTHER YEARS	Exports in 2018 (kg)	Peak Year Exports (kg)	Total Exports 1992-2019 (January) (kg)
Russia		400,049	3,084,745	12,619,102
Germany		1,803,712	2,087,390	7,546,865
Netherlands		838,194	2,131,500	6,121,173
United Kingdom		0	2,159,387	5,908,899

Source: U.S. Census Bureau Trade Data. U.S. Census Bureau does not recommend a formal way of citing data used from its website. See https://www.census.gov/about/policies/citation.html.

Notes: Exports of foreign goods (re-exports) consist of commodities of foreign origin that have previously been admitted to U.S. Foreign Trade Zones or entered the United States for consumption, including entry into a U.S. Customs and Border Protection–bonded warehouse, and, at the time of exportation, are in substantially the same condition as when imported.

Countries are shown by cumulative imports from 1992 to January 2019. Only four countries had foreign exports from 1992 to January 2019.

Enriched Uranium

Historically, the federal government operated gaseous diffusion uranium enrichment facilities at Oak Ridge, TN,[55] Paducah, KY, and Portsmouth, OH, which supplied enriched uranium for defense purposes during World War II and the Cold War. The federal government used uranium enrichment services at these sites to produce enriched uranium for private contracts to commercial nuclear power plants after 1967. As of 2019, these enrichment sites have ceased operations and are undergoing decontamination and decommissioning managed by DOE's Office of Environmental Management. DOE estimated that program life-cycle costs for decontamination and decommissioning collectively for the three sites range from $70.8 billion to $78.3 billion.[56]

As of 2019, the Urenco gas centrifuge uranium enrichment facility near Eunice, NM, is the only operational uranium enrichment facility in the United States. The Urenco facility has the capacity to supply approximately one third of the annual requirements for U.S. reactors.[57] Several other

[55] Multiple uranium enrichment plants with different uranium enrichment methods were located at Oak Ridge. Notably, the largest was the K-25 gaseous diffusion uranium enrichment facility that operated until 1987.

[56] DOE, *FY2019 Congressional Budget Request*, March 2018, p. 77.

[57] World Nuclear Association, *US Nuclear Fuel Cycle*, February 2019, http://www.world-nuclear.org/information-

domestic uranium enrichment facilities began NRC licensing, though no enrichment facilities are proceeding with construction.[58]

According to the World Nuclear Association, the majority of commercial uranium enrichment services are performed in China, France, Germany, the Netherlands, Russia, the United Kingdom, and the United States.[59] Smaller-capacity uranium enrichment plants are located in several other countries. Urenco operates uranium enrichment facilities in the United Kingdom, Germany, and the Netherlands.[60]

According to the ITC trade data, the top five countries exporting enriched UF_6 to the United States in 2018 were the Netherlands (785,046 kg), Germany (591,108 kg), Russia (547,768 kg), and the United Kingdom (461,187 kg) (**Table 7**).

Between 1993 and 2013, downblended[61] Russian HEU supplied approximately half of the enriched uranium used in U.S. domestic reactors under the Russian HEU agreement, known as the Megatons to Megawatts program.[62] This U.S.-Russian agreement provides for the purchase of 500 MT of downblended HEU from dismantled Russian nuclear weapons and excess stockpiles for commercial nuclear fuel in the United States.[63] After the Megatons to Megawatts program expired in 2013, imports of enriched uranium from Russia decreased by approximately 50% **(Table 7)**. Today, the enriched uranium from Russia imported into the United States comes from mined and milled uranium concentrate, not from downblended uranium from weapons. The enriched uranium that is imported from Russia, or any other country, may have been mined and processed in various other countries, including the United States.[64]

Table 7. Annual U.S. Imports of Enriched Uranium Hexafluoride ($enUF_6$) by Country

HTS 2844.20.00.20

Country	1992-2019 (January) PEAK YEAR / OTHER YEARS	Imports in 2018 (kg)	Peak Year Imports (kg)	Total Imports 1992-2019 (January) (kg)
Russia		547,768	1,235,535	20,036,341
United Kingdom		461,187	982,980	10,689,617
Netherlands		785,046	785,046	7,886,118

library/country-profiles/countries-t-z/usa-nuclear-fuel-cycle.aspx.

[58] See NRC, *Fuel Cycle Facility Licensing and Construction*, March 2017, https://www.nrc.gov/materials/fuel-cycle-fac/new-fac-licensing.html.

[59] World Nuclear Association, *Uranium Enrichment*, 2019, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx.

[60] See Urenco, "Global Operations," https://urenco.com/global-operations.

[61] "Downblending" is the process of converting relatively higher enriched uranium to relatively lower enriched uranium. See World Nuclear Association, *US Nuclear Fuel Cycle*.

[62] 42 U.S.C. §2297h-10(b).

[63] 31 C.F.R. §540.305.

[64] For example, NRC export license XSOU8847 authorized the shipment of seven million kilograms of uranium concentrate from the Honeywell Plant, IL, to Technabexport in Moscow, Russia, for "conversion, enrichment and return for use in U.S. nuclear power stations." NRC, *Export License*, NRC Form 250, September 6, 2018, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18250A064.

Country	1992-2019 (January) PEAK YEAR OTHER YEARS	Imports in 2018 (kg)	Peak Year Imports (kg)	Total Imports 1992-2019 (January) (kg)
France		0	986,876	6,831,553
Germany		591,108	591,108	6,221,151

Source: U.S. Census Bureau Trade Data. U.S. Census Bureau does not recommend a formal way of citing data used from its website. See https://www.census.gov/about/policies/citation.html.

Notes: Countries are shown by cumulative imports from 1992 to January 2019.

Fuel Fabrication

Three fuel fabrication facilities are located in the United States: (1) Global Nuclear Fuel Americas plant in Wilmington, NC; (2) Westinghouse Columbia Fuel Fabrication Facility in Columbia, SC; and (3) Framatome facility in Richland, WA.[65] Fuel fabrication facilities are located in multiple countries that may offer various services (conversion, pelletizing, rod/assembly) and capacity of those services.[66]

Uranium Purchases vs. Uranium Imports

ITC data separates uranium material by the type and quantity that physically entered or exited the United States. ITC data does not estimate the amount of uranium materials purchased by utilities for a given year. ITC data does not infer the quantities of uranium materials used, stored, or processed by a nuclear utility and reactor operator. ITC data differs from the EIA data reporting, which may combine purchases by country for uranium concentrate, uranium hexafluoride, and enriched uranium as equivalents of U_3O_8.

The EIA data indicates the country of origin of uranium purchased by U.S. nuclear utilities and reactor operators. EIA data does not necessarily indicate that those materials were directly imported into the United States as a given uranium material from that country.

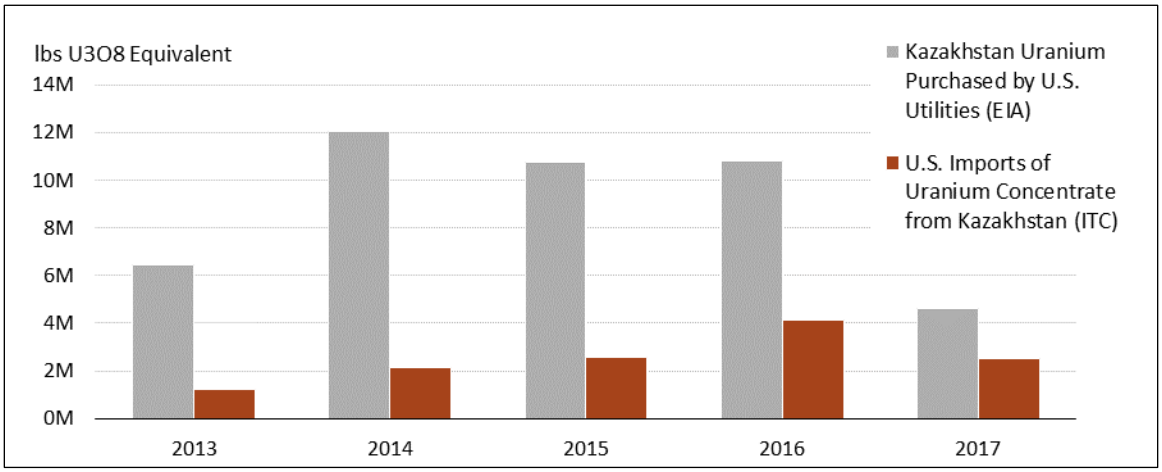
Comparing ITC and EIA data for Kazakhstan provides some insight into the flow of uranium materials through the global nuclear fuel cycle. According to the World Nuclear Association, Kazakhstan has been the world's leading producer of uranium concentrate since 2009 and produced 21,700 tons of uranium in 2018.[67]

[65] See NRC, *Locations of Fuel Cycle Facilities*, November 6, 2018, https://www.nrc.gov/info-finder/fc/.

[66] See World Nuclear Association, *Nuclear Fuel and Its Fabrication*, updated April 2019, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/fuel-fabrication.aspx.

[67] World Nuclear Association, *Uranium and Nuclear Power in Kazakhstan*, updated April 2019, http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/kazakhstan.aspx.

Figure 4. Kazakhstan Uranium Comparison: EIA and ITC Data



Source: CRS summarized data from U.S. Census Bureau Trade Data and U.S. Energy Information Administration, Table 3: Uranium purchased by owners and operators of U.S. civilian nuclear power reactors by origin country and delivery year, 2013-2017, https://www.eia.gov/uranium/marketing/html/table3.php.

Notes: Uranium hexafluoride and enriched uranium were not imported to the U.S. from Kazakhstan between 2013 and 2017. ITC data do not indicate whether uranium concentrate imports from Kazakhstan were exclusively mined or milled in Kazakhstan. CRS converted uranium concentrate data to U_3O_8 equivalents by assuming 1 kg U_3O_8 (eq) = 0.848 kg U and 2.2 lbs. U_3O_8 (eq) = 1 kg U_3O_8 (eq).

Between 2013 and 2017, uranium concentrate imports from Kazakhstan into the United States were 18%-54% of the uranium purchases by U.S. nuclear utilities and reactor operators (**Figure 4**). The difference between the uranium purchased by utilities and the uranium concentrate imported into the United States may represent some portion of the origin material that was converted, enriched, and/or stockpiled in other countries prior to being imported into the United States in the same or as a different uranium material.[68]

For example, a portion of Kazakhstan uranium purchased by U.S. utilities may have been produced as uranium concentrate in Kazakhstan and subsequently transported to conversion facilities in France for the production of UF_6. After conversion, the UF_6 may have been transported to an enrichment facility in the Netherlands for the production of enriched UF_6. Finally, the enriched UF_6 may have been imported into the United States for fuel fabrication and ultimately used in a U.S. nuclear reactor. This comparison of the reported EIA and ITC data with uranium purchases and imports from Kazakhstan illustrates how enriched UF_6 is imported from countries such as Germany, the United Kingdom, and the Netherlands, whereas U.S. nuclear utilities and reactor operators reportedly purchased no uranium originating from those countries.[69] Uranium purchases and imports may vary from year to year.

[68] The difference between these two independently collected datasets broadly reflects the differences between uranium purchases (EIA) and uranium imports (ITC). There are other factors that could explain the discrepancies between these two agency's datasets including, but not limited to, data collection and reporting methods, differences between data collection and reporting periods, and the agencies' classification of various types of materials.

[69] EIA, *Uranium Marketing Annual Report*, Table 3: Uranium purchased by owners and operators of U.S. civilian nuclear power reactors by origin country and delivery year, 2013-2017, https://www.eia.gov/uranium/marketing/html/table3.php.

Current Issues

On January 16, 2018, two U.S. domestic uranium mining companies petitioned the U.S. Department of Commerce (DOC) to investigate whether uranium imports from foreign state-owned enterprises—such as those in Russia, China, and Kazakhstan—pose a threat to national security.[70] The investigation into uranium import restrictions has sparked a debate among uranium producers; uranium mine and mill operators; and nuclear utilities, reactor operators, and suppliers. Uranium producers assert that a heavy reliance on foreign uranium constitutes a national security risk and threatens the viability of domestic uranium production. Conversely, nuclear utilities and reactor operators contend that increased fuel costs from trade restrictions would place additional financial burdens on nuclear utilities, potentially causing the premature shutdown of economically marginal nuclear power plants.

Regardless of actions taken under Section 232 by the current Administration, long-term economic viability issues of these interconnected industries in the United States remains uncertain.[71] The uranium Section 232 investigation also raises policy questions about the role of Congress under Section 232. Under current federal law, trade actions imposed by the President under Section 232 do not require congressional approval apart from actions related to petroleum imports.[72]

Congress may consider, as a broad policy question, the federal role in issues associated with the front end of the nuclear fuel cycle. The uranium materials and service industry delivers fuel for commercial nuclear power reactors, which are largely traded and purchased under private contracts in a global marketplace. Similar to other energy markets, uranium supply is an issue on which Congress may or may not elect to intervene. As discussed previously, the United States ceased production of HEU for weapons in 1964 due to the determination of sufficient stockpiles. Fuel for nuclear naval propulsion is supplied by government HEU stockpiles, and the production of HEU for naval propulsion ended by 1992. Questions about the sufficiency of the defense uranium stockpile and future uranium requirements for defense and other proposes are beyond the scope of this report.

Section 232 Investigation: Uranium Imports

Section 232 of the Trade Expansion Act of 1962 (19 U.S.C. §1862) provides the President with the ability to impose restrictions on certain imports based on an affirmative determination by DOC that the product under investigation "is being imported into the United States in such quantities or under such circumstances as to threaten to impair the national security."[73] The industry petition called for the President to enact a quota, pursuant to Section 232, on uranium imports such that "25% of the average historical consumption will be reserved for newly produced U.S. uranium." On July 18, 2018, DOC began an investigation into uranium imports under Section 232.[74] DOC's Bureau of Industry and Security (BIS) accepted public comments until September 10, 2018.

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[70] Energy Fuels Resources and Ur-Energy USA, *Petition for Relief Under Section 232 of the Trade Expansion Act of 1962 from Imports of Uranium Products that Threaten National Security*, January 16, 2018.

[71] For example, see some of the economic issues discussed in CRS Report R44715, *Financial Challenges of Operating Nuclear Power Plants in the United States*, by Phillip Brown and Mark Holt.

[72] 19 U.S.C. §1862(f).

[73] For more information about Section 232, see CRS Report R45249, *Section 232 Investigations: Overview and Issues for Congress*, coordinated by Rachel F. Fefer and Vivian C. Jones.

[74] DOC, Bureau of Industry and Security, "Notice of Request for Public Comments on Section 232 National Security

The statute establishes a process and timelines for a Section 232 investigation but does not provide a clear definition of *national security*, allowing the executive branch to use a broad interpretation, and the potential scope of any investigation can be expansive. DOC has a maximum of 270 days to provide the President with a report of the findings and recommendations of the investigation. DOC submitted a report to the President on April 14, 2019.[75] The report has not been made public. If DOC determines that imports are a threat to national security and recommends trade actions, the President has a maximum of 90 days (until July 13, 2019) to agree or disagree with DOC's findings and determine what trade actions, if any, to implement in the judgment of the President.[76] The President's trade actions are to be implemented no later than 15 days after that decision, and he is to submit a written justification to Congress within 30 days.

DOC conducted a Section 232 investigation for uranium imports in 1989.[77] The investigation was initiated at a time when U.S. utilities imported 37.5% of the actual or projected domestic uranium requirements from foreign sources for two consecutive years. No trade actions were imposed as a result of that investigation.

Stakeholders on both sides of the debate generally agree that the proposed quotas would increase fuel costs for nuclear utilities and increase revenues for domestic uranium mining. However, the extent that these costs will increase remains uncertain. A report sponsored by the Nuclear Energy Institute concluded that a 25% quota could increase fuel costs by $500 million to $800 million annually and potentially higher in the years immediately following implementation.[78] An economic study funded by the petitioners estimated that uranium mining revenues from a 25% quota would increase by $551 million to $690 million per year and would increase fuel costs by $0.41 per megawatt-hour.[79] Another study estimated that the $0.41 per megawatt-hour increase in fuel costs for nuclear generators would translate to approximately $317 million per year.[80]

Concerns of Uranium Producers and Local Communities

Domestic uranium producers, national and state mining associations, and other companies associated with uranium production generally support trade restrictions on uranium imports.[81] Some elected officials—including the U.S. Senators from Wyoming, one of the largest uranium-producing states—have supported trade actions on uranium imports.[82] The Section 232 petition

Investigation of Imports of Uranium," 83 *Federal Register* 35204-35205, July 25, 2018.

[75] Ellyn Ferguson, "Trump Weighs Tariffs or Quotas on Uranium Imports," *Roll Call*, April 16, 2019.

[76] 19 U.S.C. §1862(c): "(i) determine whether the President concurs with the finding of the Secretary, and (ii) if the President concurs, determine the nature and duration of the action that, in the judgment of the President, must be taken to adjust the imports of the article and its derivatives so that such imports will not threaten to impair the national security."

[77] DOC, Bureau of Export Administration, The Effect of Imports of Uranium on the National Security. An Investigation under Section 232 of the Trade Expansion Act of 1962, as amended (19 U.S.C. 1862), September 1989, https://www.bis.doc.gov/index.php/forms-documents/section-232-investigations/88-uranium-1989/file.

[78] NorthBridge Group, *The Market Impact of Proposed US Uranium Import Quotas on the U.S. Nuclear Power Industry*, July 2018, https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/northbridge-uranium-quota-201807.pdf.

[79] Energy Fuels Resources (USA) Inc. and Ur-Energy USA Inc., *Petition for Relief Under Section 232 of the Trade Expansion Act of 1962 from Imports of Uranium Products that Threaten National Security*, January 16, 2018. p.36.

[80] Clearview Energy Partners, *Yellowcake, Black Gold and Congressional Red Lights*, July 23, 2018.

[81] Stakeholders include but are not limited to the Colorado Business Roundtable; Colorado Mining Association; Montrose, CO, Chamber of Commerce; San Juan County Commission, Utah; Texas Mining and Reclamation Association; Wyoming Mining Association, and Utah Mining Association.

[82] Senate Committee on Environment and Public Works, "Barrasso Applauds Trump Administration Decision to

asserts that the long-term viability of the domestic uranium production industry is threatened by unfair market practices by foreign state-owned enterprises. Supporters of the petition anticipate that trade quotas would provide domestic uranium producers relief by increasing the price of uranium and subsequently increasing domestic uranium production. According to advocates of this approach, increased uranium prices and production may offer direct and indirect employment opportunities and economic stimulus to local economies.

The Wyoming Mining Association offered support to uranium import actions in its comment letter:

> WMA believes the petition sets forth a compelling case that the current state of the domestic uranium mining industry is not simply a result of foreign competition legitimately underpricing domestic producers. It now is clear that foreign, state-mandated and state-supported uranium production is thwarting our domestic industry's ability to compete in an oversupplied and underpriced market.[83]

Other U.S. producers that own and operate uranium production facilities in other countries have expressed caution regarding the idea of imposing a trade action. For example, Cameco has uranium assets in the United States, Canada, and Kazakhstan. Cameco operates the largest operational uranium recovery capacity in the United States: the Smith Ranch-Highland ISR operation in Wyoming.

During the comment period, Cameco stated that it "does not support the specific quota proposed by the petitioners, as it is unrealistic in its estimate of feasible US uranium production capabilities; would be difficult to implement and harmful to responsible participants in the US nuclear energy industry; and could ultimately increase U.S. dependence on state-controlled uranium supplied by the countries of concern as listed in the petition."[84]

Concerns of Nuclear Utilities and Reactor Operators and Suppliers

Representatives from nuclear utilities and reactor operators, industry trade groups, think tanks, converters, enrichers, and foreign governments have opposed trade actions on uranium imports proposed by the petitioners.[85] Nuclear utilities and reactor operators asserted quotas on uranium imports may increase fuel costs, causing financially vulnerable nuclear reactors to shut down earlier than currently planned. The Ad Hoc Utilities Group, collectively representing U.S. nuclear generators,[86] asserted, "Imports assure the security of nuclear fuel supply and the reliability of the

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Investigate Uranium Imports," press release, July 18, 2018, https://www.epw.senate.gov/public/index.cfm/2018/7/barrasso-applauds-trump-administration-decision-to-investigate-uranium-imports; MJ Clark, "Wyoming Senators, Mining Association in on Federal Uranium Imports Probe," *Wyoming Business Report*, July 19, 2018, https://www.wyomingnews.com/news/from_the_wire/wyoming-senators-mining-association-in-on-federal-uranium-imports-probe/article_990b24d2-8b17-11e8-891e-9faf4a69a5be.html.

[83] Wyoming Mining Association, "RE: Notice of Request for Public Comments on Section 232 National Security Investigation of Imports of Uranium, DOCKET BIS-2018-0011," comment letter, September 7, 2018. https://www.regulations.gov/document?D=BIS-2018-0011-0398.

[84] Cameco, "Cameco Submits Comments to the US Department of Commerce Section 232 Investigation," press release, September 25, 2018, https://s3-us-west-2.amazonaws.com/assets-us-west-2/news/18_09_25_Cameco_Submits_Comments_US_232_Investigation.pdf.

[85] Including, but not limited to: ConverDyn; Dominion Energy; Nuclear Energy Institute; The Heritage Foundation; Urenco, Inc.; TENAN; and Xcel Energy.

[86] See "Public Comments on Behalf of the Ad Hoc Utilities Group," September 25, 2018, https://www.regulations.gov/document?D=BIS-2018-0011-0245: "Members include Ameren Missouri, Dominion Energy Services, Inc. on behalf of Virginia Electric and Power Company and Dominion Energy Nuclear Connecticut, Inc., Duke Energy Carolinas, LLC, and Duke Energy Progress, LLC, Energy Northwest, Entergy Operations, Inc. and Entergy Nuclear Operations, Inc.,

electric grid. Nuclear generators source from a diverse set of suppliers at all stages of the nuclear fuel cycle with the majority of supply coming from the U.S. and our allies in Canada, Australia, and Western Europe."[87]

Operators of U.S. conversion and enrichment facilities in the United States have publicly expressed concern with uranium import quotas.[88] Malcolm Critchley, the marketing agent for ConverDyn, stated that quotas "would undoubtedly cause suppliers to divert uranium [from Honeywell] … to other locations outside of the United States if the supplier did not have a known domestic customer at the time of import."

U.S. uranium enrichers shared these concerns. Melissa Mann, the president of Urenco USA—the only uranium enrichment operation in the United States—noted that, with the ceased operations at Honeywell and the DOE termination of its barter program, "there is currently no source of natural UF_6 in the United States."[89] Urenco receives deliveries of UF_6 from Cameco's Port Hope facility in Canada and Orano's Comhurex II in France. She cautioned, "Should remedies in the uranium Section 232 investigation be imposed that disrupt deliveries of UF_6 to [New Mexico], operation of the facility—and the $5 billion investment in the plant—could be jeopardized," and "the lack of feed material to enrich would also jeopardize delivery of low enriched uranium to fuel fabricators, putting at risk utility reactor reload schedules and reactor operations."[90]

Some utilities have dismissed claims about the dependence on foreign sourced uranium and vulnerability to supply chains disruptions. For example, Dominion Energy noted that concerns with foreign supply disruptions were exaggerated because "in the past five years, our only delays or interruptions in nuclear fuel component deliveries have been from U.S. based fuel cycle suppliers."[91]

Legislation and Congressional Oversight

In March 2018, the Trump Administration imposed tariffs on foreign imports of steel and aluminum pursuant to Section 232. This was the first implementation of trade actions under Section 232 since 1986. Some Members of Congress have questioned whether the Administration's use of Section 232 on steel and aluminum imports are an appropriate use of the trade statute and rely upon broad interpretations on the definition of *national security*. Bills have been introduced in both chambers (H.R. 1008 and S. 365) in the 116th Congress that would amend Section 232 to provide for congressional disapproval of certain trade actions with the enactment of a disapproval resolution.

The uranium Section 232 investigation was discussed in a September 6, 2018, hearing by the Senate Appropriations Committee, Subcommittee on Commerce, Justice, Science, and Related Agencies. At that hearing, Richard Ashooh, Commerce Assistant Secretary for Export

Exelon Generation Company, LLC, Florida Power & Light Company and NextEra Energy Resources (on behalf of its nuclear affiliates), Pacific Gas and Electric Company, PSEG Nuclear LLC, South Carolina Electric & Gas Company, and Xcel Energy Services Inc."

[87] See "Public Comments on Behalf of the Ad Hoc Utilities Group."

[88] "Utilities Say US Uranium Import Quota Could Spur Reactor Shutdowns," *Nucleonics Week, S&P Global, Platts*, October 11, 2018, pp. 1, 8.

[89] See "Utilities Say US Uranium Import Quota Could Spur Reactor Shutdowns."

[90] See "Utilities Say US Uranium Import Quota Could Spur Reactor Shutdowns."

[91] Dominion Energy, Comments on Section 232 National Security Investigation of Imports on Uranium (Federal Register 83 FR 35204, dated July 25, 2018; Docket ID BIS-2018-0011), September 25, 2018, https://www.regulations.gov/document?D=BIS-2018-0011-0717.

Administration at BIS, suggested that the uranium investigation had prompted the agency to consider "creative ideas" outside of using import restrictions.[92]

On February 5, 2019, the House Committee on Natural Resources requested from the uranium producers that had submitted the petition to DOC "[a]ll documents and communications … relating to the Department of Commerce Section 232 Investigation on uranium."[93]

Domestic Uranium Production Viability

The Section 232 investigation was initiated at a time of economic uncertainty for uranium producers—uranium miners and millers—in the United States. Domestic uranium production experienced a sharp decline during the early 1980s and has remained at comparatively low levels over the past 25 years.

Recently, global demand for uranium has been depressed due to a number of factors, including the continued shutdown of most Japanese nuclear power reactors following the Fukushima Daiichi accident.[94] In 2018, domestic uranium concentrate production was 1.5 million pounds, down approximately 40% from 2017 and at the lowest annual production levels since 1950.[95] U.S. uranium producers have dealt with poor market conditions by decreasing production and imposing employment layoffs.[96] Domestic uranium producers have reportedly engaged in purchasing uranium concentrate on the market at lower spot market prices to fill delivery obligations at relatively higher contract prices.[97] States have proposed legislation intended to provide some financial relief for domestic uranium producers.[98]

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[92] U.S. Congress, Senate Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies, Hearing to conduct oversight of the Bureau of Industry and Security, the International Trade Administration, and the United States International Trade Commission, https://www.appropriations.senate.gov/hearings/conduct-oversight-of-bureau-of-industry-and-security-international-trade-administration_us-international-trade-commission, 115th Cong., 2nd sess., September 6, 2018. See discussion around 2:07:00, Richard Ashooh, Assistant Secretary for Export Administration at the Bureau of Industry and Security, whose activities include managing the U.S. export control and treaty compliance systems and promoting U.S. strategic technology leadership. BIS is responsible for investigating the effects of imports on national security under Section 232 of the Trade Expansion Act of 1962. BIS is also in charge of the exemption process for tariffs implemented as a result of Section 232 investigations. "But what I will say, the lessons we've learned on things like ongoing 232s on uranium, is to not automatically think in terms of import restrictions, but rather look at creative ideas."

[93] Raul M. Grijalva, Chairman, Committee on Natural Resources, and Alan S. Lowenthal, Chairman, Subcommittee on Energy and Natural Resources, letter to Mark Chalmers, President and CEO, Energy Fuels, and Jeffrey T. Klenda, President and CEO, UR-Energy, February 5, 2019, https://naturalresources.house.gov/imo/media/doc/Grijalva%20Lowenthal%20Letter%20Requesting%20Information%20From%20Uranium%20Companies%20Feb.%205%202019.pdf.

[94] DOE, *Analysis of Potential Impacts of Uranium Transfers on the Domestic Uranium Mining, Conversion, and Enrichment Industries*, p. 45: "There are a number of important market factors that have influenced the relationship between supply and demand (hence price) since DOE inventory transfers began. These other factors include: demand losses due to the Japanese reactor shutdowns following the Fukushima Daiichi accident, demand losses due to changes in German energy policy, increased uranium production in Kazakhstan, increased secondary supply created using excess enrichment capacity (both underfeeding and upgrade of Russian enrichment tails), the planned ramp-up of Russian uranium under the Suspension Agreement, and the end of the U.S. Russian HEU Agreement in 2013."

[95] EIA, *Domestic Uranium Production Report 4th Quarter 2018*, February 6, 2019, https://www.eia.gov/uranium/production/quarterly/pdf/qupd.pdf.

[96] Caroline Ballard, "Uranium Miner Cameco Announces Layoffs in Wyoming and Nebraska," *Wyoming Public Media*, April 22, 2016.

[97] "UxC's Nick Carter Predicts 'Gradual Upward Movement' of Uranium Price," *Northern Miner*, January 26, 2019.

[98] For example, the Wyoming state legislature introduced a bill that would provide a sliding scale tax proportional to market prices designed to aid state uranium producers by applying lower tax when uranium prices are depressed.

Potential questions for Congress include whether it may consider legislation intended to sustain the economic viability of the domestic uranium production industry and whether it may consider policies that would favor domestically sourced uranium over foreign sourced uranium procured through the global uranium marketplace.

Nuclear Power Viability

U.S. nuclear power plants face economic issues and a general uncertainty over their long-term economic viability.[99] Of the 98 operating nuclear reactors, 12 reactors are scheduled to shut down, prior to license expiration, by 2025.[100] The Plant Vogtle nuclear expansion project in Georgia, currently the only new construction of nuclear power reactors in the United States, is reportedly billions of dollars over budget and years behind schedule.[101] A 2018 report by the Union of Concerned Scientists asserts that roughly one-third of nuclear power plants are unprofitable and that modest changes in costs may have profound impacts on other nuclear power plants' economic viability.[102]

Questions for Congress could include whether trade restrictions, such as quotas or tariffs, on uranium imports may lead to early closure of economically vulnerable plants and, if so, what the possible economic consequences are to communities and electricity rate payers that those plants serve.

Tribes and Environmental Considerations

Some Native American tribes and public interest groups in the United States opposed trade actions on uranium imports due to concerns that uranium import restrictions would promote increased domestic uranium mining and milling operations.[103] These groups suggest that many of the health and environmental issues associated with historical uranium mining and milling have not been adequately addressed. Persistent soil, surface, and groundwater contamination associated with historical uranium mining and milling remains a concern for some communities. For example, federal, state, and tribal agencies manage environment impacts associated with historical uranium mining and milling operations that occurred on Navajo Nation lands.[104]

Heather Richards, "With Uranium Mining Under Pressure, Wyoming Lawmakers Suggest Tax Cuts," *Casper Star Tribune*, January 20, 2019.

[99] For example, see some of the economic issues discussed in CRS Report R44715, *Financial Challenges of Operating Nuclear Power Plants in the United States*, by Phillip Brown and Mark Holt.

[100] See remarks by Senator Lamar Alexander, U.S. Congress, Senate Committee on Appropriations, Subcommittee on Energy and Water Development, *Review the Future of Nuclear Power: Advanced Reactors*, 116th Cong., 1st sess., January 16, 2019.

[101] Kristi E. Swartz, "Pressure Is on Georgia Power to Finish Vogtle," *Energy Wire*, September 28, 2018, https://www.eenews.net/stories/1060100025.

[102] Steve Clemmer et al., *The Nuclear Power Dilemma*, Union of Concerned Scientists, November 2018.

[103] For example, see Wishtoyo Chumash Foundation, *Comment regarding Department of Commerce Investigation into Uranium Sanctions*, September 24, 2018, https://www.regulations.gov/document?D=BIS-2018-0011-0695. Also see Uranium Watch, *RE: Comments on Section 232 National Security Investigation of Imports of Uranium. 83 Fed. Reg. 35204, July 25, 2018. Regulations.gov Docket No. BIS-2018-0011*, September 25, 2018, https://www.regulations.gov/document?D=BIS-2018-0011-0712.

[104] See U.S. Environmental Protection Agency, *Federal Actions to Address Impacts of Uranium Contamination in the Navajo Nation*, September 24, 2014, https://www.epa.gov/sites/production/files/2016-06/documents/nn-five-year-plan-2014.pdf.

Questions for Congress could include an examination of environmental impacts associated with historical domestic uranium mining and milling operations, potential long-term environmental or public health consequences of expanding domestic uranium production, and the adequacy of bonding and long-term financial assurance requirements for current or future uranium production operations undergoing site reclamation and decommissioning.

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