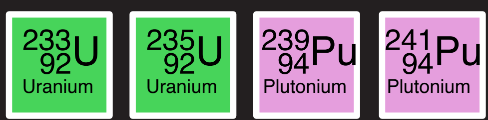
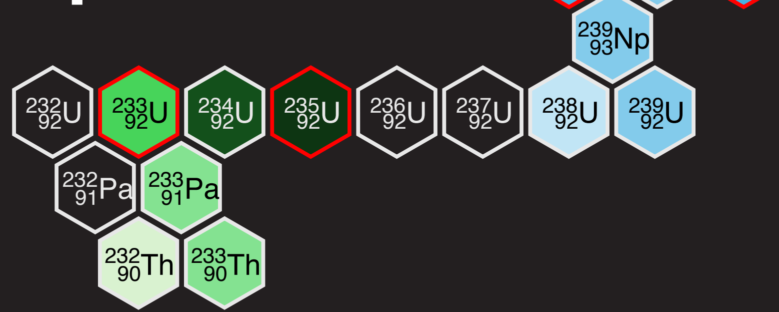
Position Statement #47

Management of Surplus U.S. Nuclear Material





Fissile isotopes are rare and valuable, as they can fuel nuclear reactors. They can also be used in nuclear weapons, so they must be carefully controlled. Only one fissile isotope exists in nature (uranium-235). Manmade fissile isotopes are produced at great expense through neutron bombardment of more abundant fertile isotopes, generally in a nuclear reactor. U-238 (99.3% of natural uranium) is the source of two fissile plutonium isotopes (Pu-239 and Pu-241), and thorium-232 (100% of natural thorium) is the source of fissile U-233. Fissile isotopes are also potential sources of valuable fission, decay, and activation products.

The U.S. government has various inventories of fissile material. Most of the material was to support the nuclear weapons program, to power naval nuclear propulsion, or to fuel research and test reactors at universities and national labs. Today, substantial quantities are considered "surplus" and lack a government-funded mission. Fissile materials pose challenges, including storage costs, security costs, and a complicated and politicized history.

The materials also possess tremendous potential benefits, such as for advanced reactor fuels and as sources of medical isotopes. However, the government needs clearer, more durable policies for these applications. Some past government-led programs failed to accomplish their goals, and costly materials are being permanently converted into waste, rather than used to create economic value. In some cases, today's actions and plans are the result of past political conditions, and these circumstances are no longer relevant.

The plutonium disposition program is one key example. Begun in the 1990s following the end of the Soviet Union, it was initiated with the primary purpose of addressing the concern that stockpiles of surplus weapons-grade plutonium in Russia were vulnerable to theft or diversion. The U.S. and Russia agreed to carry out a cooperative program in which both countries would convert surplus plutonium into mixed oxide fuel (MOX) and use it in commercial nuclear reactors. That program struggled due to much-higher-than-expected costs and deteriorating relations between the two countries. After termination of the U.S. MOX project, the U.S. transitioned to a "dilute-and-dispose" program to process U.S. plutonium and send it to the Waste Isolation Pilot Plant for disposal. That program was halted in one of four executive orders issued May 23, 2025 ("Reinvigorating the Nuclear Industrial Base," EO 14302), and the Department of Energy (DOE) now plans to make the remaining plutonium available to industry for advanced reactor fuels. Other potentially valuable inventories of nuclear materials also exist across the DOE complex that the government should seek to make available to industry to evaluate for preservation, transfer, and productive use.

Recently, nuclear fuel costs for current reactors have increased significantly, and some proposed new reactors face a shortage of required fissile material (e.g., high-assay low-enriched uranium, or HALEU). These issues could be alleviated by making portions of the plutonium, U-235, and U-233 inventories available to industry. Reorienting fissile material management policy toward beneficial use would be consistent with the letter and spirit of EO 14302 and another 2025 EO, "Deploying Advanced Nuclear Reactor Technologies for National Security" (EO 14299).

To address these challenges and opportunities, the American Nuclear Society recommends the following actions:

1. Establish fissile material disposition policies to prioritize energy production and innovation over waste disposal. ANS endorses the halt to surplus plutonium "dilute-and-dispose" in the May 23, 2025, Executive Order 14302, "Reinvigorating the Nuclear Industrial Base."

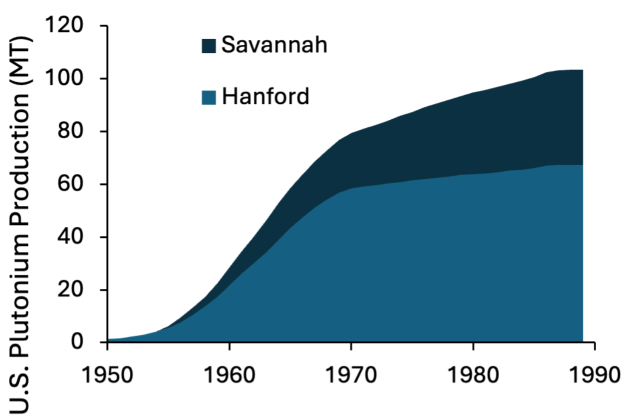
2. Congress should enact legislation to prioritize beneficial use of fissile material over disposal.
3. The DOE should conduct reviews involving potential industry users to identify alternatives to disposal for management of fissile materials.
4. Incentivize private industry to convert fissile materials into usable reactor fuels (e.g., initiate fuel qualification programs that accelerate the use of fuels produced from recovered materials).
5. Support pilot projects to demonstrate the use and value of fissile materials in next-generation reactors.

These steps would preserve valuable resources, bolster energy security, and position the U.S. as a leader in sustainable nuclear power.

Background Information

Weapons-Grade Plutonium (WG-Pu)

WG-Pu typically contains over 90% Pu-239, with less than 7% Pu-240. WG-Pu generally exists as metallic pits from dismantled weapons, but inventories include oxides and other chemical forms from conversion or stabilization (for storage) activities. From 1944 to 2009, the Department of Energy and its predecessor, the Atomic Energy Commission, produced or acquired about 111.7 metric tons (MT) of plutonium, with most (103.4 MT) produced at the Hanford and Savannah River Sites during the Cold War. After various removal and disposal efforts, about 95.4 MT remain as of 2009.



Sources: (DOE, 1996), *Plutonium: The First 50 Years*; also, (DOE, 2012), *The U.S. Plutonium Balance, 1944-2009*, an update of *Plutonium: The First 50 Years*

Fig. 1. U.S. Plutonium production during the Cold War.

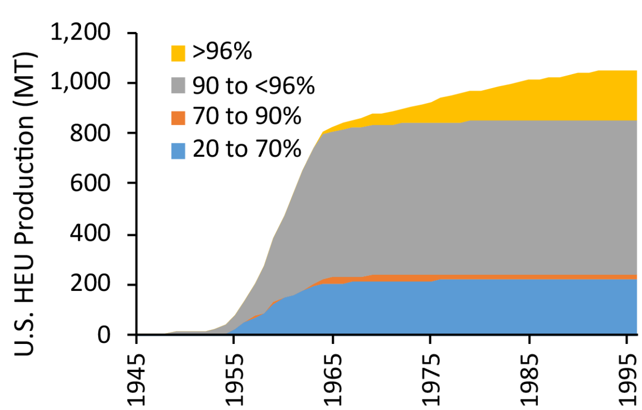
Via two declarations (52.5 MT in 1994, 9 MT in 2007), the DOE has declared about 61.5 MT of WG-Pu[1] as surplus to national security needs. This was part of a broader effort to reduce the U.S. nuclear arsenal following the dissolution of the Soviet Union in 1991. In 2000, the Plutonium Management and Disposition Agreement (PMDA) was signed, and the U.S. and Russia pledged to dispose of at least 34 MT of surplus WG-Pu, primarily by irradiating it in a mixed oxide fuel (MOX) in commercial reactors. However, challenges have arisen regarding the PMDA's implementation, and new approaches are needed.

Until recently,[2] the DOE was pursuing a "dilute-and-dispose" approach to its own surplus plutonium. Since plutonium does not exist in nature and there are no significant stockpiles of nonfissile plutonium, it cannot be downblended in the same way as high-enriched uranium (HEU) or U-233. Dilute-and-dispose mixes an adulterant with the plutonium and packages it in a secure container for disposal in the Waste Isolation Pilot Plant (WIPP) in New Mexico. Dilute-and-dispose is expensive and does not degrade the material's weapons attractiveness as much as isotopic downblending or irradiation in a reactor. It also uses WIPP disposal capacity that could be needed for U.S. transuranic waste disposal. Due to the breakdown of the U.S.–Russia plutonium disposition agreement, the rapid disposition of U.S. WG-Pu is no longer required to support international nonproliferation programs. Given the alternative uses for the plutonium in support of clean energy goals, the rush to bury the material at WIPP deserves reconsideration.

WG-Pu at Savannah River National Laboratory (SRNL) (about 12 MT), Hanford (6.6 MT), and the Pantex Plant in Texas (67.7 MT) could be used as a surrogate fuel to develop spent/used nuclear fuel (SNF/UNF) waste-burning reactors and initiate fuel qualification programs, such as those planning on using recycled material from reprocessing facilities. This would establish a credible alternative to limited high-assay low-enriched uranium (HALEU) fuel availability and make productive use of a material produced by the U.S. at great expense. Furthermore, the use of WG-Pu in advanced reactors would destroy and degrade inventories in a similar manner to the MOX program that the U.S. and Russia previously pursued together, making this approach likely to be more politically supportable in the context of international safeguards.

High-Enriched Uranium (HEU)

Reportedly, the U.S. produced about 1,045 MT of HEU through 1996, with 740.7 MT remaining in inventory.[3]



Source: (DOE, 2001), *Highly Enriched Uranium: Striking a Balance: A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996*

Fig. 2. U.S. HEU production during the Cold War.

Subsequent use of the material included national security needs and downblending for commercial or research purposes, with reductions resulting in a disclosed inventory of about 567 MT by 2019.[4] Portions of this inventory, especially that considered surplus to national security needs, potentially could be used for advanced reactor fuels, depending on the isotopic and chemical composition. Current forms include metal cores from dismantled nuclear weapons, as well as oxides, fluorides, and unirradiated and irradiated fuels (naval propulsion or research reactors).

Surplus HEU generally originates from the Strategic Arms Reduction Treaty (START) or other agreements. The Megatons to Megawatts Program (1993–2013) successfully downblended 500 MT of Russian HEU into LEU, fueling about 10% of U.S. electricity generation for 20 years.

HEU has long been considered ideal as a starter fuel for Th/U-233 thermal-spectrum breeder reactors and would be very effective if used in space-based microreactors (surface fission power or propulsion).[5]

Uranium-233 (U-233)

U-233 was successfully used in the Molten Salt Reactor Experiment (MSRE) before the entire Molten Salt Breeder Reactor (MSBR) program was canceled in the early 1970s during budget reduction and consolidation efforts. The high potential of the technology was acknowledged by decision-makers of that era in later memoirs. Because no modern program was ever created to pursue use of the material, the DOE is now downblending the country's U-233 inventory to create a waste material that will be transported to the Nevada National Security Site (NNSS).

Less than 1 MT of U-233 is at Oak Ridge National Laboratory (ORNL), and the inventory is currently being downblended by the DOE to convert it into waste. During his tenure as ORNL's lab director (1955–1973), Dr. Alvin Weinberg consolidated U-233 from various sources around the country to ORNL for use in MSBR development. MSBRs (a type of thermal breeder reactor) have a specific fissile inventory of approximately 1 MT/GWe, which is needed at startup only and is then continuously replaced by new U-233 bred on-site from thorium. The ORNL inventory could be used to start prototype micro- or space reactors.

Valuable cancer isotopes are also generated from U-233, which is the parent isotope for a unique decay chain not found in nature. Actinium-225 and bismuth-213 are highly effective in targeted alpha therapies, and their commercial use is limited only by the limited supply.

Fissile Materials from Fertile and Waste Material Recovery

Fertile Materials. Fertile isotopes like U-238 (99.3% of natural uranium) and Th-232 (100% of natural thorium) are not directly fissile. When they absorb a neutron, however, they become fissile Pu-239 and U-233. Both uranium (2.7 ppm) and thorium (9.6 ppm) are moderately abundant in Earth's crust and significantly more abundant than nature's only fissile isotope, U-235 (0.019 ppm), which is about as rare as silver (0.075 ppm), platinum (0.005 ppm), and gold (0.004 ppm).

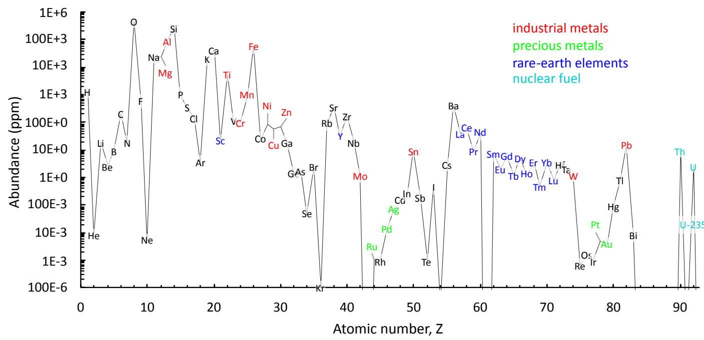


Fig. 3. Abundance of elements on Earth.

Because of their abundance and the fact that only one neutron is required to breed fissile fuel materials, fertile isotopes can be used as the fuel input for breeder reactors, an essential step for scaling nuclear energy to provide a significant portion of global primary energy needs. Uranium would be used as the fuel feed for fast breeder reactors, while thorium could fuel fast- or thermal-spectrum breeders.

Waste Materials. Uranium can be found concentrated in natural ore or in depleted uranium waste streams. Similarly, thorium can also be found in ore bodies or in waste streams from rare earth or other mining activities. Uranium can also be found in dilute concentrations in seawater (3.3 ppb, or 3.3 micrograms per liter). Additional details for these and other waste materials are outlined in the following paragraphs.

Depleted uranium is a byproduct of the uranium enrichment process, with the depleted tails being ~0.25% U-235, down from the ~0.7% of natural uranium, which was used to create the enriched uranium product (~3%–5% U-235). Most of the natural uranium fed to enrichment facilities goes into the depleted uranium stream, and the U.S. has ~700,000 MT of depleted uranium hexafluoride (UF_6) stored at former enrichment facilities (e.g., Paducah, Kentucky) and government sites. Inventories continue to grow as enriched fuels continue to be used. Depleted uranium can be used in armor-piercing projectiles and tank armor due to its high density, low radioactivity, and metallurgical properties. It can also be used in radiation shielding in medical and industrial applications to protect against gamma radiation. For energy, depleted uranium could be used in a closed fast reactor nuclear fuel cycle, reducing the need for fresh uranium mining. Though plans are to fuel near-future advanced fast reactors with HALEU, it is likely that future fast breeder reactors would require a feed of natural or depleted uranium to continue producing plutonium fuel for the reactor.

Thorium is three to four times more abundant than uranium on Earth and consists of one extremely long-lived radioisotope. Various types of solid fuels and liquid fuels containing thorium are of modern interest for advanced reactors that would operate in either burner or breeder (open or closed) fuel cycles. Thorium inventories have accumulated around the world from past nuclear activities. Thorium mining is not specifically performed today, as large volumes of thorium are generated in rare earth and other mining processes and are considered to be waste. Mined thorium is currently sent to low-level-waste facilities. However, recognition of thorium as a fuel type could help establish the front end of a domestic thorium fuel cycle. Thorium is the potential fuel feed for thermal-spectrum or fast-spectrum breeder reactors (uranium can fuel only fast breeder reactors)

Transuranics (TRU), including plutonium, can be found in the 90,000+ MT of SNF/UNF in the U.S. (see ANS Position Statement #3),[6] sitting at reactor sites where it was generated, awaiting availability of one or more DOE geologic repositories or consolidated storage locations. Approximately 95% of the SNF/UNF theoretically could be used to generate energy (the remaining U-238 and U-235). Approximately 1% (900 MT) is plutonium (Pu-239, Pu-240, and Pu-241). Americium (~0.15%, primarily Am-241), curium (~0.01%, mostly Cm-242 and Cm-244), and neptunium (~0.05%, primarily Np-237) are also present. Some of these TRU isotopes are fissile, such as Pu-239 and Pu-241. Others are fertile and can be converted into fissile isotopes in reactors. The TRU elements have long half-lives, such as Pu-239 at 24,100 years, and help drive the need for geologic disposal due to the long-term radiotoxicity and heat generation. Advanced reactors would be ideal consumers of these materials. TRU isotopes fission very efficiently in fast reactors. Though reprocessing of SNF/UNF was banned in the U.S. by Presidents Ford and Carter, that decision was reversed by President Reagan, and the primary obstacle to recycling development is economics. In recent years, enriched uranium fuel prices have risen, and there is growing interest in SNF/UNF-derived advanced reactor fuels (e.g., U-TRU fuel). Several bills have been proposed in Congress to support the development of advanced reprocessing technologies to make these materials available to advanced reactor stakeholders and pursue productive recycle and reuse—as encouraged by Executive Order 14302.[2]

Derivative Products. Fissile materials not only serve as fuel to efficiently produce energy but also yield valuable byproducts through fission, decay, and activation processes. Fission products like molybdenum-99 (Mo-99) are critical for medical imaging, enabling the production of technetium-99m (Tc-99m) for millions of diagnostic procedures each year, while strontium-90 (Sr-90) could potentially be used in radioisotope thermoelectric generators (RTGs) for space missions. Decay products from fissile isotopes, such as actinium-225 (Ac-225) and bismuth-213 (Bi-213) derived from U-233, show promise in targeted cancer therapies due to their alpha-emitting properties (short travel distance reduces damage to non-cancer cells). Additionally, activation products like plutonium-238 (Pu-238), currently produced by neutron irradiation of neptunium-237 (Np-237), power deep-space missions, as seen in NASA's Mars rovers. These derived products highlight the broader potential of fissile materials beyond energy production, underscoring the need to preserve surplus inventories for scientific, medical, and exploratory applications rather than disposing of them as waste.

Conclusion

Fissile isotopes are rare and valuable, and historic inventories could be put to productive use as advanced reactor fuel sources and to initiate fuel qualification programs, such as those planned on the use of recovered material. Fertile isotopes are more abundant and can be used to make fissile isotopes. Derivative fission, activation, and decay products can be very valuable if harvested from current and future waste inventories. Proper management of these materials would avoid waste management challenges and costs, improve energy security and abundance, and contribute to a cleaner energy future. Executive orders issued in May 2025 have clarified that U.S. policy is to prioritize use of fissile materials as fuels over other activities, especially those related to disposing of these materials.

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