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SUMMARY

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Lance N. Larson
Analyst in Environmental Policy

Mark Holt
Specialist in Energy Policy

Considerations for Reprocessing of Spent Nuclear Fuel

Nuclear reactors generate about 20% of U.S. commercial electric power and almost half of the nation's low carbon electricity generation. However, nuclear reactors also produce highly radioactive spent nuclear fuel (SNF) that results from the fission (splitting) of uranium nuclei in the reactor fuel. SNF must be isolated from the environment for thousands of years to prevent harm.

About 91,000 metric tons of SNF is stored at nuclear plant sites around the United States, awaiting consolidated storage and permanent underground disposal. The Nuclear Waste Policy Act (P.L. 97-425), as amended, designated Yucca Mountain, NV, as the only candidate site for a national deep geologic repository for the disposal of SNF and other high-level nuclear waste. Political and legal opposition to the project has indefinitely delayed the licensing, construction, and operation of the proposed Yucca Mountain repository.

Direct disposal of SNF, as currently planned in the United States, is called the "once through" fuel cycle. About 95% of SNF consists of uranium from the fresh fuel that was originally loaded into the reactor and 1% consists of fissile plutonium produced from irradiated uranium, both of which can be used in new fuel. The remaining 4% of SNF consists of highly radioactive fragments of uranium and plutonium (fission products) that must be disposed of.

SNF can be reprocessed through chemical dissolution or melting to allow uranium and plutonium to be separated from the fission products and made into new fuel. Repeated reprocessing of SNF is called the "closed cycle," a major alternative to the once-through cycle. Reprocessing is currently carried out in France, Russia, and a few other countries; however, there are no commercial reprocessing operations in the United States. Reprocessed uranium and plutonium currently can be recycled only once into new fuel for current reactor designs, as additional recycling would require advanced reactors, specifically fast neutron reactors.

The United States developed technology for the reprocessing of SNF during World War II and for decades operated some of the largest reprocessing facilities in the world, primarily for nuclear weapons material production purposes. Commercial reprocessing activities in the United States ended during the 1970s and early 1980s because of rising costs and policy concerns about the potential worldwide growth of stockpiles of weapons-usable plutonium.

Interest in reprocessing in the United States has renewed among some policymakers and stakeholders primarily because of its potential for reducing the volume and toxicity of nuclear waste. In principle, indefinite reprocessing of SNF could eliminate the need for permanent disposal of uranium and plutonium, which would be made into new fuel, and require permanent disposal of only the fission products, which would be immobilized in glass or other insoluble materials. However, there are potential waste-related disadvantages. The degree to which total waste volumes and long-lived toxicity would be reduced by any future reprocessing and recycling remains uncertain—along with the costs—and largely dependent on future technology development.

Congress has supported the Department of Energy's reprocessing research and development program in recent years through a funding authorization in the Energy Act of 2020 (Division Z of P.L. 116-260) and subsequent annual appropriations. The Energy Act of 2020 and the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) authorized and appropriated more than $2 billion for demonstrations of advanced reactors, including fast neutron reactors that could indefinitely recycle SNF plutonium. In the 118th Congress, hearings on nuclear waste management and recycling were held in the House Energy and Commerce and Senate Energy and Natural Resources Committees, and the House Appropriations Committee in report language called for commercialization of reprocessing by 2033 (H.Rept. 118-580).

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Introduction

Nuclear reactors produce highly radioactive spent nuclear fuel (SNF) as a result of power production. During reactor operation, some of the uranium in nuclear fuel is split (fissioned) to produce energy. The resulting fission products are intensely radioactive and thermally hot. Some of the uranium also is converted to plutonium. After several years, reactor fuel can no longer efficiently sustain a nuclear chain reaction and is placed into storage as SNF.

The Nuclear Waste Policy Act of 1982,[1] as amended, designated Yucca Mountain, NV, as the only location where the Department of Energy (DOE) could construct a national high-level nuclear waste repository for the permanent disposal of SNF and high-level radioactive waste. Political and legal opposition to the project has indefinitely delayed the licensing, construction, and operation of the proposed Yucca Mountain repository. As a result, currently SNF is stored at the nuclear power plant where it was produced.

Reprocessing refers generally to the technical process of extracting uranium, plutonium, and certain other elements from the SNF to be used as new fuel. Advocates of reprocessing cite two major potential benefits: (1) extracting and reusing the fissile material (uranium-235 and plutonium-239)[2] to take advantage of the potential embedded energy value remaining after the nuclear fuel has been "burned"[3] and removed from a nuclear reactor, and (2) reducing the long-lived radioactivity of nuclear waste to facilitate disposal options.

The United States developed technology for the reprocessing of SNF during World War II and for decades operated some of the largest reprocessing facilities in the world to produce plutonium for nuclear weapons. From 1966 to 1972, a reprocessing plant operated in West Valley, NY, to separate uranium and plutonium for commercial reactor fuel. However, commercial reprocessing was subsequently abandoned in the United States because of high costs and concerns about nuclear weapons proliferation. Other countries, such as France, the United Kingdom, and Russia, operate commercial reprocessing plants. Interest in reprocessing efforts in the United States has renewed among some policymakers and stakeholders due to considerations pertaining to alternative solutions for the management of high-level nuclear waste and the development of "advanced" nuclear reactors, some of which would include a fuel cycle supported by reprocessed SNF.

Some have argued for Congress to support reprocessing operations as an option to eliminate or decrease the volume of nuclear waste required for a permanent repository, as well as to utilize fuel that could be produced from SNF. On the other hand, others may argue that reprocessing could lead to increased proliferation risks, waste management and disposal issues, and

[1] P.L. 97-425, 42 U.S.C. §§10101 et seq.

[2] In addition to these fissile materials, a variety of isotopes that are used in medical, industrial testing and scientific activities can be extracted through chemical separations from spent nuclear fuel (SNF). In addition to producing energy by reusing the fissile material, reusing the isotopes takes advantage of the energy and money invested in the original front end of the nuclear fuel cycle for activities from mining, processing, and enrichment to create the fresh nuclear fuel.

[3] While the term *burn* is often used to refer to fission in a reactor, and the term *high burnup* reactors refers to the process of increasingly making more efficient use of uranium, no combustion occurs and no combustion products (e.g., carbon dioxide [CO_2], sulfur oxides [SOx], nitrogen oxides [NOx], or particulates) are emitted directly from nuclear power production. Also, the reason for removing nuclear fuel from a reactor is not primarily the burnup or loss of fission products (e.g., U-235), but rather the buildup of fission products that absorb neutrons and decrease the fuel's ability to generate heat cost-effectively. Much of the U-235, and hence the potential energy value, that is put into a reactor as fresh fuel is later taken out as spent fuel, along with newly created fissile materials, such as plutonium, and fission products that result from the splitting of uranium and plutonium nuclei. Reprocessing separates out these fission products from fissile materials that can be reused for nuclear fuel.

uncertainties about costs. This report describes reprocessing in the context of the nuclear fuel cycle and provides general considerations regarding U.S. policy, nonproliferation, the regulatory framework, waste management and disposal, environmental concerns, and economics. The final section discusses recent congressional action involving reprocessing, high-level waste management, and advanced reactors.

Background

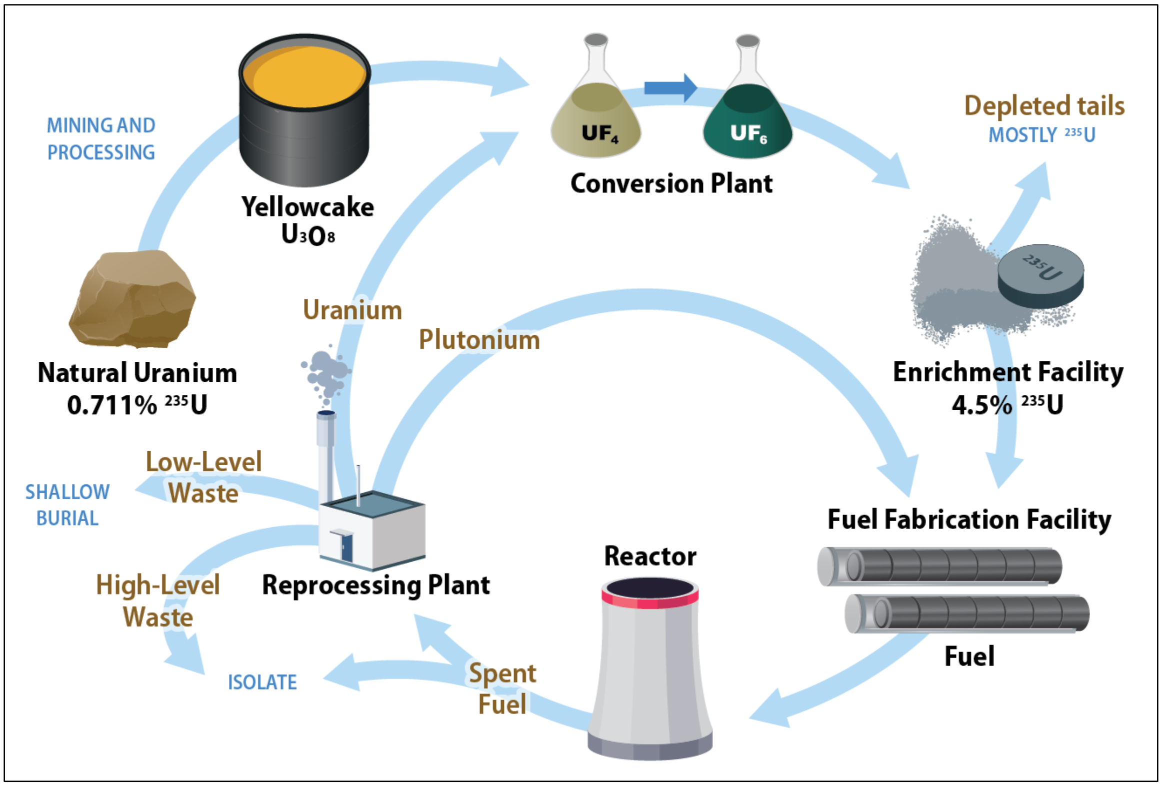
The U.S. Nuclear Fuel Cycle

The U.S. nuclear fuel cycle includes the process of extracting uranium from the earth, enriching the uranium to increase the concentration of the fissile form of uranium (U-235), fabricating the enriched uranium into fuel rod assemblies capable of being used in nuclear reactors for generating electric power, and managing the resulting SNF. Commercial civilian nuclear reactors in the United States use low-enriched uranium (LEU) oxide fuel assemblies to generate nuclear power through fission reactions.[4] The fuel rods are bundled into fuel assemblies for placement in the reactor core. These assemblies facilitate a controlled nuclear fission chain reaction that generates heat, which is used to drive turbines to produce electric power. Approximately every 18-24 months, the reactor fuel becomes incapable of economically producing power and must be replaced (i.e., it is considered "spent"). Fuel assemblies removed from the reactor following power production are called SNF.[5]

[4] Natural uranium has an isotopic composition of approximately 0.71% U-235, the fissile isotope of uranium. Civilian nuclear power fuel is generally enriched to 3%-5% U-235. Until 2013, uranium enrichment in the United States was largely performed using a gaseous diffusion technology. Currently, one uranium enrichment plant, which employs gas centrifuge technology, operates in the United States.

[5] The Nuclear Waste Policy Act of 1982, as amended, defines *SNF* as the fuel assemblies "withdrawn from a nuclear reactor following irradiation." 42 U.S.C. §10101.

Figure 1. Nuclear Fuel Cycle



Source: U.S. Government Accountability Office, *Commercial Spent Nuclear Fuel - Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution*, GAO-21-603, 2021.

SNF is currently stored in one of two ways: in storage pools or dry casks. Immediately following power production, SNF is discharged from the reactors and stored in pools of water on-site, as it remains intensely radioactive and thermally hot. Wet pools provide regulated conditions allowing the fuel to cool, while water is circulated and maintained to keep it from boiling off and uncovering the fuel. In dry cask storage, the SNF is stored in sealed, steel canisters surrounded by radiation shielding materials, such as steel, concrete, or other materials. Wet storage capacity for SNF can be limited, prompting most reactor sites to store SNF using a combination of wet storage and dry casks.[6] As of December 2022, 91,000 metric tons of SNF were stored in the United States, mostly at nuclear power plant sites, increasing by about 2,200 metric tons per year.[7]

The U.S. nuclear power industry is considered an "open fuel cycle" or "once-through fuel cycle," as new uranium as fuel must be mined and processed to replace the nuclear fuel used in reactors. The once-through fuel cycle uses only a fraction of the 0.7% of U-235 found in natural uranium, plus a small fraction of the dominant isotope U-238 that is converted to plutonium during reactor operation. The vast majority of the initially mined uranium is planned for disposal.

In a "closed fuel cycle," reprocessing of SNF would extract uranium, plutonium, and certain other elements from the SNF to be used as new fuel. Plutonium is a particularly important fissile

[6] In dry storage, spent fuel is placed in sealed containers filled with inert gas and cooled by natural air circulation. For more information, see CRS Report RL33461, *Civilian Nuclear Waste Disposal*, by Mark Holt.

[7] Pacific Northwest National Laboratory, *Spent Nuclear Fuel and Reprocessing Waste Inventory*, December 2024, https://curie.pnnl.gov/system/files/SNF%20and%20Rep%20Waste%20Inventory%20PNNL%2033938%20Rev.%201.1_0.pdf.

material that can be used in nuclear reactor fuel instead of enriched uranium. Proponents of a closed fuel cycle assert this cycle could continue indefinitely and be used to fuel some advanced reactors so that only relatively short-lived fission products would need permanent disposal.[8] High-level waste from reprocessing would initially be similar to spent fuel in heat and radioactivity but would decay to near background levels after several hundred years because plutonium and other long-lived radioactive materials would be removed and used as new fuel. In addition, proponents assert the closed fuel cycle could extract from the fuel many times the amount of energy that could be produced with the once-through cycle.[9]

Reprocessing of Spent Nuclear Fuel

In general, reprocessing of SNF involves separating uranium, plutonium, and minor actinides[10] from the SNF for reuse in other purposes, such as nuclear warhead production or fuel for further civilian use. Because separated plutonium is one of two materials that can be used to make a nuclear weapon (the other being enriched uranium), international controls on spent fuel reprocessing are a fundamental element in weapons nonproliferation policy. The United States has long sought to discourage additional countries from building reprocessing facilities. The U.S. Nuclear Regulatory Commission (NRC) defines *reprocessing* as "the processes used to separate spent nuclear reactor fuel into nuclear materials that may be recycled for use in new fuel and material that would be discarded as waste."[11]

According to the World Nuclear Association (WNA), all commercial reprocessing facilities operating in five other countries use the PUREX (plutonium-uranium extraction) technique, although with some variation depending upon the fuel cycle needs.[12] In general, the PUREX technique involves a series of processing steps, including dissolving the SNF in nitric acid; chemically separating uranium (U) and plutonium (Pu) using various organic solvent extraction methods; and finally converting the Pu and U to respective powder forms, plutonium oxide (PuO_2) and uranium oxide (UO_2). In part to address issues experienced with potentially harmful environmental releases, proliferation vulnerability, and costs, other reprocessing technologies have been proposed, such as UREX (uranium extraction only) and UREX+,[13] that would not fully separate plutonium.[14] Additionally, researchers have examined other reprocessing techniques, such as pyroprocessing and electrometallurgical refining.[15] Not all such processes for recycling

[8] Argonne National Laboratory, *Nuclear Fuel Recycling Could Offer Plentiful Energy*, 2012, https://www.anl.gov/article/nuclear-fuel-recycling-could-offer-plentiful-energy.

[9] For example, see World Nuclear Association, "Processing of Used Nuclear Fuel," 2020, https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.

[10] Actinides are a group of elements on the periodic table from mass number 89 (actinium) to 103 (lawrencium). In the context of SNF, minor actinides are typically americium, neptunium, and curium.

[11] U.S. Nuclear Regulatory Commission, *Reprocessing*, https://www.nrc.gov/materials/reprocessing.html#background.

[12] The World Nuclear Association (WNA) identifies five countries with facilities capable of commercial reprocessing: France, Russia, Japan, United Kingdom, and India. WNA, *Processing of Used Nuclear Fuel*, updated 2020, https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx.

[13] There have been many different proposed UREX+ designs with various products and waste streams. See ibid.

[14] M. C. Regalbuto, "Alternative Separation and Extraction: UREX+ Processes for Actinide and Targeted Fission Product Recovery," in *Advanced Separation Techniques for Nuclear Fuel Reprocessing and Radioactive Waste Treatment* (Woodhead Publishing, 2011).

[15] World Nuclear Association, "Processing of Used Nuclear Fuel," updated December 2020, https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx. See section on "Electrometallurgical 'Pyroprocessing.'" Additional discussion of reprocessing technology can be found in Section 4.3.6 of National Academies of Sciences, Engineering, and Medicine (NASEM), *Merits and Viability of Different*
(continued...)

SNF would result in fully separated plutonium, which is a weapons-usable material.[16] If plutonium is not fully separated from the highly radioactive fission products in SNF, it is generally considered less attractive to be used as weapons material.

The volume and radiotoxicity of waste products from reprocessing depends on the separation process employed, which affects both the extent to which SNF is separated and the degree of transmutation[17] of critical components.[18] In general, the waste liquid remaining after reprocessing SNF and separating Pu and U (which make up about 97% of the spent fuel) is considered high-level waste (HLW), which is highly radioactive and thermally hot. The liquid HLW contains the highly radioactive fission products and minor actinides that constituted about 3% of the spent fuel before it was reprocessed.[19] This liquid waste can be conditioned with certain dry materials in order to convert (i.e., vitrify) it into a more stable borosilicate glass for long-term management. U.S. reprocessing plants associated with defense activities stored liquid HLW in large underground tanks where treatment and disposal remain pending. Data on existing waste treatment technologies are available from currently operating plants such as DOE's large HLW glassification (i.e. vitrification) facility at the Savannah River Site in South Carolina (Defense Waste Processing Facility), which started operating in 1996.

A 2023 study from the National Academies of Sciences, Engineering, and Medicine (referred to in this report as the "NASEM study")[20] noted that reprocessing generates a wide variety of waste streams: "Some of these waste streams are captured in waste forms for disposal in low-level waste disposal facilities or a geologic repository, while others are released to the environment either in liquid or gaseous forms."[21] For a future commercial reprocessing facility, any degree of risk from emissions would be dependent upon NRC regulations governing these operations, and compliance with those regulations.

Considerations for U.S. Reprocessing

The following sections discuss considerations associated with developing commercial reprocessing operations in the United States. As noted above, reprocessing operations exist in five other countries, but not in the United States. These sections provide general considerations regarding U.S. policy, nonproliferation, the regulatory framework, waste management and disposal, environmental concerns, and costs. These sections do not intend to address the technical and/or economic viability of any proposed reprocessing or advanced reactor designs, nor do they assume that any future reprocessing operations could not address these considerations.

Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors, 2023, https://doi.org/10.17226/26500.

[16] National Research Council, *Review of DOE's Nuclear Energy Research and Development Program*, Washington, DC, 2008, pp. 48-49.

[17] *Transmutation* is a change in number of protons or neutrons in an atomic nucleus through nuclear reactions or nuclear decay.

[18] M. C. Regalbuto, "Alternative Separation and Extraction: UREX+ Processes for Actinide and Targeted Fission Product Recovery," in *Advanced Separation Techniques for Nuclear Fuel Reprocessing and Radioactive Waste Treatment* (Woodhead Publishing, 2011).

[19] World Nuclear Association, *Processing of Used Nuclear Fuel*, 2020, https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx.

[20] NASEM, *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors*, 2023, https://doi.org/10.17226/26500.

[21] See ibid., p. 136.

U.S. Policy—History and Developments

U.S. policies that support commercial reprocessing have varied since reprocessing activities began for defense activities during World War II. Fissile materials were first produced by the U.S. government by enriching natural uranium to uranium-235 (Oak Ridge, TN) and reprocessing irradiated uranium fuel and separating out the plutonium (Hanford, WA) during World War II under the Manhattan Project.

In the Atomic Energy Act of 1946 (AEA), Congress defined "fissionable materials" to include plutonium, uranium-235, and other materials determined to be capable of releasing substantial quantities of energy through nuclear fission.[22] Congress amended the AEA in 1954 to define "special nuclear material" to supplant "fissionable materials," and included uranium-233, material determined to be special nuclear material, and any artificially enriched material.[23] Additionally, the AEA of 1954 authorized the Atomic Energy Commission (AEC) to license commercial nuclear reactors and eased restrictions on private companies using special nuclear materials. The U.S. government held the title to any special nuclear materials used or produced at a licensed U.S. facility.

Interest in commercial reprocessing of SNF began in the 1950s. In 1966, the AEC granted a commercial reprocessing permit to Nuclear Fuel Services for the West Valley facility, near Buffalo, NY. The facility operated until 1972 when it shut down for upgrades to meet stricter regulatory requirements and never operated again.[24] During operation, 2,500 cubic meters (m^3) of HLW was produced, stored, and later vitrified.[25] During roughly the same time, other commercial reprocessing operations were proposed or partially constructed, but never operated.[26]

Nonproliferation

The reprocessing of SNF results in at least the partial separation of plutonium, a key material in nuclear weapons. As a result, concern about nuclear weapons proliferation throughout the world is a major element in the debate over reprocessing policy. Light water nuclear reactors (LWRs)—the type of all commercial nuclear reactors operating in the United States—create plutonium during operation when uranium-238 absorbs neutrons and undergoes radioactive decay to become plutonium-239. Thus, SNF removed from a reactor includes various plutonium and uranium isotopes. This plutonium poses relatively low proliferation risk unless it is separated from fission products.[27] Once separated through reprocessing, the plutonium could be used to produce fuel for LWRs; fast neutron breeder reactors; or nuclear warheads, provided the availability of technical expertise and specialized facilities.[28] The 2023 NASEM study noted that "fuel cycles involving

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[22] P.L. 79-585.

[23] P.L. 83-703.

[24] Congressional Budget Office, *Nuclear Reprocessing and Proliferation: Alternative Approaches and their Implications for the Federal Budget*, May 1977.

[25] Qin-Hong Hu et al., "Sources of Anthropogenic Radionuclides in the Environment: A Review," *Journal of Environmental Radioactivity* (2010).

[26] General Electric proposed a reprocessing plant at Morris, IL, and Allied-General Nuclear Services began construction at a facility in Barnwell, SC.

[27] National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium* (Washington, DC: The National Academies Press, 1994), https://doi.org/10.17226/2345. The report proposed a "Spent Fuel Standard" as a basis for comparing the risks to the fissile material "self-protected" in a spent fuel rod.

[28] U.S. Department of Energy (DOE), *Additional Information Concerning Underground Nuclear Weapon Test of Reactor-Grade Plutonium*, https://www.osti.gov/opennet/forms?formurl=document/press/pc29.html; DOE, (continued...)

reprocessing and separation of fissile material that could be weapons usable pose greater proliferation and terrorism risks than the once-through uranium fuel cycle with direct disposal of spent fuel, as the separated fissile material would not be uniformly mixed with highly radioactive fission products."[29] International safeguards against diversion of plutonium and enriched uranium for weapons, as discussed below, can be a means of reducing proliferation risk.

Existing global stockpiles of plutonium and uranium, which are substantial, also pose a proliferation concern. According to the International Panel on Fissile Materials, as of December 31, 2022, the global stockpile of separated plutonium was 560 metric tons (MT), of which 140 MT was available for weapons.[30] The remaining 420 MT of plutonium stockpiles were characterized as not suitable for weapons, because they were produced outside of weapon programs, covered by obligations prohibiting the use in weapons, or not directly suitable for weapons.[31] The largest stockpiles of plutonium available for weapons were generally in countries where reprocessing has occurred for defense or commercial purposes: Russia (88.0 MT), the United States (38.4 MT), the United Kingdom (3.2 MT), France (6.0 MT), and China (2.9 MT). Global stockpiles of highly enriched uranium (HEU) were 1,245 MT as of December 31, 2022, and mostly located in Russia (55%) and the United States (39%), with lesser amounts held in other countries.

These existing stockpiles of plutonium and HEU can be regarded as both an energy resource for nuclear power plant reactor fuel as well as a liability due to the storage costs and proliferation risk. A variety of domestic and international systems and institutions provide safeguards for these stockpiles.

The International Atomic Energy Agency (IAEA) was established in 1957 to ensure that civilian nuclear facilities and materials, such as those related to reprocessing, are not diverted for military uses.[32] Safeguards are designed to enable the IAEA to detect the diversion of nuclear material from peaceful purposes to nuclear weapons uses.[33] Increasing the stockpiles of separated fissile materials through reprocessing would likely increase the requirements for IAEA technical staff

"Plutonium: The First 50 Years," DOE/DP-0137, 1996; and Gregory S. Jones, "Reactor-Grade Plutonium and Nuclear Weapons: Ending the Debate," *Nonproliferation Review*, vol. 26 (2019), pp. 1-2, 61-81, https://doi.org/10.1080/10736700.2019.1603497.

[29] NASEM, *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors*, 2023, https://doi.org/10.17226/26500, p. 13.

[30] International Panel on Fissile Materials, *Fissile Material Stocks*, https://fissilematerials.org/#:~:text=Fissile%20material%20stocks&text=The%20global%20stockpile%20of%20separated,not%20directly%20suitable%20for%20weapons. Different countries have different criteria for determining what material are available for weapons.

[31] See ibid.

[32] The International Atomic Energy Agency (IAEA), an autonomous intergovernmental organization that has a relationship agreement with the United Nations, has 172 member states, including the United States. The agency's missions include promoting nuclear power, nuclear safety, nuclear security, and nuclear technology for medical and agricultural purposes, as well as implementing safeguards agreements in more than 180 countries.

[33] IAEA safeguards are designed "to provide credible assurance to the international community that nuclear material and other specified items are not diverted from peaceful nuclear uses" (IAEA, *The Safeguards System of the International Atomic Energy Agency*). The Nuclear Nonproliferation Treaty (NPT) requires nonnuclear-weapon states parties to conclude comprehensive IAEA safeguards agreements. Such agreements apply safeguards "on all nuclear material in all nuclear activities in a State" (IAEA, *IAEA Safeguards Glossary 2001 Edition*, International Nuclear Verification Series No. 3). The NPT defines a *nuclear-weapon state* as "one which has manufactured and exploded a nuclear weapon or other nuclear explosive device" prior to January 1, 1967. These states are China, France, Russia, the United Kingdom, and the United States. All other countries are not nuclear weapon states. See also CRS Report R41910, *Nuclear Energy Cooperation with Foreign Countries: Issues for Congress*, by Paul K. Kerr, Mary Beth D. Nikitin, and Mark Holt.

and other resources to maintain these safeguards. The IAEA recognized in 2021 that it was addressing a "growing gap between demand and resources … [with] increasing demands on the Agency for support."[34]

While domestic and international safeguards are intended to prevent the diversion of a sufficient quantity and quality of fissile materials to fabricate a nuclear explosive device, some have expressed concerns that these materials may be obtained by a politically unstable state or a terrorist organization—a well-financed organization with the ability to hire or recruit the necessary abilities to create a nuclear explosive device—if domestic reprocessing were to lack sufficiently high security measures. Furthermore, reprocessing plants would require a high level of security, with associated increased costs, to safeguard the materials stored at the facility.[35]

Another long-standing concern has been the policy signal potentially sent to other countries if the United States resumes reprocessing. Any proposal to resume commercial reprocessing in the United States to make reactor fuel may raise concerns about an increase in global commerce in fissile material and undermine long-standing U.S. policy to discourage the development of reprocessing and enrichment capacity in non-nuclear-weapon states.[36]

The use of plutonium-based fuel in nuclear power plants has been a recurring congressional issue. When Congress deliberated funding for the Global Nuclear Energy Partnership (GNEP) in 2008 (see "Reprocessing Policy History, In Brief" below), the House committee report accompanying the Energy and Water Development and Related Agencies Appropriations Act, 2008, expressed concern that too many GNEP partner countries wanted to be nuclear fuel suppliers (producing enriched uranium and plutonium fuel for domestic use and export) rather than recipients. According to the report,

> At the recent DOE-sponsored international ministerial meeting on GNEP, the Administration abandoned any pretext that GNEP will promote international nuclear nonproliferation by relenting to partner demands that "partnership" countries can continue to produce weapons-usable plutonium in their reprocessing activities. The Committee is disappointed that the Administration would support any effort that leads to increased availability of plutonium anywhere in the world.[37]

Reprocessing Policy History, In Brief

When the commercial nuclear power industry was under development in the 1950s and 1960s by the U.S. Atomic Energy Commission, it was widely expected that SNF from power reactors would be reprocessed to separate the remaining uranium and plutonium for new fuel. With up to 1,000 reactors expected to be built in the United States by the end of the 20th century, reprocessing was considered essential for making the maximum use of what were believed to be limited uranium resources. Early reactors were designed with relatively small spent fuel pools to hold discharged SNF until it could be shipped to a commercial reprocessing plant. However, India's diversion of reprocessed plutonium from its nuclear power program to produce a nuclear explosive device in 1974 generated worldwide controversy about the future expansion of commercial reprocessing, including in the United States.

In 1976, President Ford announced that "the reprocessing and recycling of plutonium should not proceed unless there is sound reason to conclude that the world community can effectively overcome the associated risks of proliferation ... [and] that the United States should no longer regard reprocessing of used nuclear fuel to produce

[34] IAEA, *The Agency's Programme and Budget 2022–2023*, GC(65)/(2), 2021.

[35] Mark Hibbs and Fred McGoldrick, "A Realistic and Effective Policy on Sensitive Nuclear Activities," Carnegie Endowment for International Peace, 2013, https://carnegieendowment.org/research/2013/10/a-realistic-and-effective-policy-on-sensitive-nuclear-activities?lang=en.

[36] CRS Report RL34234, *Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear Power*, coordinated by Mary Beth D. Nikitin.

[37] U.S. Congress, House Committee on Appropriations, *Energy and Water Development Appropriations Bill, 2008*, committee print, 110th Cong., H.Rept. 110-185 (Washington: GPO, 2008), p. 67.

plutonium as a necessary and inevitable step in the nuclear fuel cycle, and that we should pursue reprocessing and recycling in the future only if they are found to be consistent with our international objectives." The following year, President Carter announced a shift in policy: "We will defer indefinitely the commercial reprocessing and recycling of plutonium produced in the U.S. nuclear power programs." In 1981, President Reagan announced that he "was lifting the indefinite ban which previous administrations placed on commercial reprocessing activities in the United States." At the same time, however, federal funding for a commercial reprocessing plant in South Carolina was terminated, and the project was abandoned.

In 1992, President George H. W. Bush announced in a statement on nuclear nonproliferation,

> I have set forth today a set of principles to guide our nonproliferation efforts in the years ahead and directed a number of steps to supplement our existing efforts. These steps include a decision not to produce plutonium and highly enriched uranium for nuclear explosive purposes and a number of proposals to strengthen international actions against those who contribute to the spread of weapons of mass destruction and the missiles that deliver them.

In 1993, President Clinton announced, "The United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes. The United States, however, will maintain its existing commitments regarding the use of plutonium in civil nuclear programs in Western Europe and Japan."

President George W. Bush in 2006 proposed to establish the Global Nuclear Energy Partnership (GNEP) with the goal of addressing issues of nuclear proliferation and nuclear waste. Through the GNEP, countries with nuclear fuel infrastructure, including the United States, would have supplied nuclear fuel and technologies to countries without nuclear power capabilities. In turn, the countries using nuclear power would agree to return the SNF, which would be reprocessed in the original country and be used as a source of fuel for reactors. In DOE's description, this aspect of GNEP would be nonproliferative because participating countries would be forgoing their own enrichment and/or separations activities.

In 2009, President Obama ended work on the previous Administration's programmatic environmental impact statement for GNEP. The program was transformed into the International Framework for Nuclear Energy Cooperation (IFNEC) under the Obama Administration and has continued as an international fuel cycle forum.

More recently, DOE continues to carry out reprocessing operations at various defense sites to manage SNF. For commercial nuclear power plants, however, the 2023 NASEM study recommended that "the current U.S. policy of using a once-through fuel cycle with the direct disposal of commercial spent nuclear fuel into a repository should continue for the foreseeable future," but also that "DOE should develop and implement a phased, long-range research and development program that focuses on advanced separations and transmutations technologies."

Sources:

- U.S. President Gerald Ford, *Presidential Documents*, vol. 12, no. 44 (1976), pp. 1626-1627.
- U.S. President Jimmy Carter, "Nuclear Power, Policy Statement by the President on His Decisions Following a Review of U.S. Policy," *Presidential Documents*, vol. 13, no. 15 (April 7, 1977).
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- National Academies of Sciences, Engineering, and Medicine, *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors* (Washington, DC: The National Academies Press, 2023), p. 85.

Regulatory Framework

As discussed above, no commercial reprocessing facilities are currently operating in the United States. If such a facility were proposed, it would be required to obtain an NRC license under the Atomic Energy Act of 1954, as amended, and would need to adhere to any other applicable federal permitting requirements.[38] The NRC has only regulated a single operational commercial reprocessing facility, at West Valley, NY, which operated from 1966 to 1972. In June 2007, the NRC commissioners directed NRC staff to conduct a regulatory gap analysis and identify regulatory requirements necessary to license reprocessing facilities.[39] In 2013, NRC staff recommended a rulemaking for reprocessing facilities based on the findings of the gap analysis. The rulemaking activities were suspended in 2016 due to "budgetary constraints and an apparent lack of commercial interest in reprocessing."[40] On July 28, 2021, NRC discontinued the rulemaking activity for spent fuel reprocessing "based on the estimated costs to conduct the rulemaking and the limited interest expressed or expected from industry to submit an application for any type of facility involving reprocessing technologies in the near-term."[41] NRC estimated the rulemaking would cost $2.5 million to complete, and did not anticipate reviewing a license application for a reprocessing facility within 10-20 years. In the event that commercial reprocessing license applications are submitted to NRC prior to implementation of new reprocessing regulations, the NRC stated it would license those facilities under current regulations, typically used for licensing of nuclear reactors.[42]

On December 29, 2022, Oklo Inc. contacted NRC to begin pre-application activities to seek a license for a commercial-scale spent fuel reprocessing facility.[43] Reportedly, Oklo is working with Argonne National Laboratory to develop electrorefining technology and to use spent fuel elements to produce new nuclear fuel.[44]

Waste Management and Contaminant Remediation Issues

Reprocessing of SNF for defense and civilian uses in the past has resulted in extensive environmental contamination and waste management challenges, particularly the treatment and disposal of stored HLW. Thus, the management and disposal of wastes from future reprocessing would be an important consideration for the operation of these facilities. While reprocessing SNF would change the nature and composition of the nuclear waste, this option would raise multiple technical, legal, and policy considerations regarding the long-term management and disposal waste produced from reprocessing operations. Under current law, wastes produced from

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[38] 42 U.S.C. §§2011 et seq.

[39] U.S. Nuclear Regulatory Commission, *Staff Requirements—SECY-07-0081—Regulatory Options for Licensing Facilities Associated with the Global Nuclear Energy Partnership (GNEP)*, ML071800084, 2007.

[40] Nuclear Energy Institute, *NEI Comments on Spent Fuel Reprocessing Rulemaking*, ML20154K554, 2020.

[41] U.S. Nuclear Regulatory Commission, "Spent Fuel Reprocessing," 86 *Federal Register* 40764, 2021.

[42] See 10 C.F.R. Part 50 - "Domestic Licensing of Production and Utilization Facilities."

[43] Oklo, *Oklo Inc. Licensing Project Plan: Fuel Recycling Technologies (Initial)*, 2022, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML22363A080.

[44] Jeff Beattie, "Eight Months After NRC's Rejection, Oklo Applies Again to License Microreactor," *Nucleonics Week*, 2022, p. 3.

reprocessing would still require disposal in a permanent geologic repository at Yucca Mountain, NV. This section discusses the history of the environmental problems resulting from past reprocessing as well as technologies and regulations to reduce environmental risk at future reprocessing plants.

U.S. government reprocessing facilities during and following World War II generally operated prior to the establishment of regulatory requirements for nuclear waste management. Thus, the ongoing remediation and waste management operations at sites where reprocessing activities occurred in support of nuclear weapons production in the United States may not be analogous to potential impacts of future commercial reprocessing operations. Historical activities at many of these facilities resulted in the contamination of various soil, surface water, and groundwater. Much of the understanding of the potential environmental impacts from the production of HLW from reprocessing have stemmed from operational experiences at reprocessing facilities for U.S. nuclear weapons production during and after World War II. Generally, the DOE Office of Environmental Management (EM) is responsible for remediating these types of sites. The nature of contaminants, areas affected, environmental and ecological issues, and remedial actions vary widely at DOE-EM sites.[45] Many of these DOE-EM sites require environmental remediation activities that will remain ongoing for decades, and require long-term stewardship in perpetuity, currently undertaken by DOE's Office of Legacy Management, after the remedial activities are complete. State and federal regulations for future commercial reprocessing facilities, and the management of the associated wastes, would be required to prevent or minimize similar potential impacts.

DOE manages HLW resulting from reprocessing SNF, generally from the historical production of nuclear warheads. In the United States, some DOE-owned or -managed sites maintain HLW inventories from reprocessing SNF, as well as material shipped there from commercial power reactors in limited circumstances. In some instances, these DOE sites may store various types of HLW and SNF.[46] At these sites, DOE has vitrified some liquid HLW to be stored on-site until it can be permanently disposed of in a future geologic repository. At some DOE sites, such as Hanford, WA, and Savannah River Site, SC, considerable amounts of HLW remain in liquid form. According to the Government Accountability Office,

> DOE oversees the treatment and disposal of about 54 million gallons of radioactive and hazardous waste at the Hanford Site in Washington State. Before treating the tank waste, DOE plans to separate it into two streams: (1) a high-activity portion, which DOE estimates will contain about 5 percent of the volume but more than 70 percent of the radioactivity; and (2) a low-activity portion, which will contain about 95 percent of the volume.[47]

Additionally, the Nuclear Waste Technical Review Board estimates the volume of vitrified HLW to increase from 3,200 m^3 to 26,300 m^3 from 2012 to 2048.[48]

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[45] For examples, see F. W. Whicker et al., "Avoiding Destructive Remediation at DOE Sites," *Science*, vol. 303, no. 5664 (2004); Joana Burger et al., "Assessing Ecological Resources for Remediation and Future Land Uses on Contaminated Lands," *Environmental Management*, vol. 34 (2004); Mark J. Peterson, Rebecca A. Efroymson, and S. Marshall Adams, "Long-Term Biological Monitoring of an Impaired Stream: Synthesis and Environmental Management Implications," *Environmental Management*, vol. 47 (2011); Joanna Burger et al., "Role of Uncertainties in Protecting Ecological Resources During Remediation and Restoration," *Journal of Toxicology and Environmental Health, Part A*, vol. 84, no. 12 (2021).

[46] CRS In Focus IF11201, *Nuclear Waste Storage Sites in the United States*, by Lance N. Larson.

[47] Government Accountability Office, *Hanford Cleanup: DOE Should Validate Its Analysis of High-Level Waste Treatment Alternatives*, GAO-23-106093, May 2023, https://www.gao.gov/assets/gao-23-106093.pdf.

[48] U.S. Nuclear Waste Technical Review Board, *Six Overarching Recommendations for How to Move the Nation's Nuclear Waste Management Program Forward*: *A Report to the U.S. Congress and the Secretary of Energy*, 2021.

The origin of radioactive waste, rather than its radiologic characteristics, often determines its classification and disposal requirements. The Nuclear Waste Policy Act (NWPA)[49] defines *SNF* as being "withdrawn from a nuclear reactor following irradiation"[50] and *HLW* as "highly radioactive material from reprocessing spent nuclear fuel."[51] Although they are quite different technically, both fall under the broader definition of "high-level radioactive waste."[52] SNF is sometimes referred to as "used" nuclear fuel.

The NWPA authorized DOE to site a geologic repository for the permanent disposal of SNF and HLW. Congress amended the NWPA in 1987 to designate Yucca Mountain as the only location to be considered by DOE to construct a national high-level nuclear waste repository. Political and legal opposition to the project has indefinitely delayed the licensing, construction, and operation of the proposed Yucca Mountain repository. NWPA authorized DOE to enter into agreements with nuclear utilities and other reactor owners to collect fees to pay for DOE's disposal of the SNF. However, because DOE had not begun operating a permanent repository as required by NWPA, the federal government has paid roughly $10.6 billion to nuclear utilities and other reactor owners pursuant to court settlements and final judgments as of September 30, 2023.[53] Under current law, without the availability of a long-term geologic repository or consolidated interim storage facility, all SNF and HLW will remain on site at 80 facilities in the United States, which are predominantly commercial nuclear power plants and DOE facilities.[54]

One of the main intended benefits of SNF reprocessing would be to decrease or eliminate the disposal of plutonium, uranium, and long-lived fission products in the SNF. Some research indicates that reprocessing SNF would decrease the surface footprint and volume required for a geologic repository, as well as reduce the overall radiotoxicity of certain waste forms intended for repository disposal.[55] The degree to which reprocessing could affect the total required HLW storage would depend on the types of reprocessing technologies employed and the waste characterizations. Nevertheless, studies have generally found that any fuel cycle concept would require some form of waste management in a geologic repository.

In the United States, wastes produced by commercial reprocessing would be regulated by NRC under the AEA. HLW produced from reprocessing may include a mix of radiological and chemical constituents. Depending upon the type of operation and the wastes produced, the facility may require permitting under other federal environmental laws, such as the Clean Air Act or the Clean Water Act. Discharges or emissions into the environment would also be subject to the terms of the NRC license and other federal permits, and the federal agency issuing the license or permit would be responsible for enforcing compliance with those requirements. The extent to which a release of constituents would affect the environment would depend on the nature of the

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[49] P.L. 97-425.

[50] 42 U.S.C. §10101(23).

[51] 42 U.S.C. §10101(12).

[52] See 42 U.S.C. §10101(23), 10 C.F.R. §60.2, 10 C.F.R. §63.2, and 40 C.F.R. §197.2. Under 42 U.S.C. §10101(12):

> The term "high-level radioactive waste" means—
>
> (A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and
>
> (B) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation.

[53] U.S. Department of Energy, *Agency Financial Report*, FY2023.

[54] CRS In Focus IF11201, *Nuclear Waste Storage Sites in the United States*, by Lance N. Larson.

[55] Robin Taylor et al., "A Review of Environmental and Economic Implications of Closing the Nuclear Fuel Cycle - Part One Wastes and Environmental Impacts," *Energies*, vol. 15, no. 1433 (2022).

constituents, the duration of the release, the amount of the release, and the location of the incident, among other factors.

In addition to the potential benefits described above, some stakeholders contend another benefit of reprocessing may be the reduced need for uranium production and the associated environmental impacts. For example, the 2023 NASEM study found that the "main advantage" of SNF reprocessing and recycling of uranium and plutonium "is the conservation of uranium resources at the front end of the fuel cycle and the associated reduction in the environmental impact of uranium mining."[56]

Economics

Economic costs and benefits are an important consideration for private and public investments in commercial reprocessing. Currently operating U.S. nuclear power plants have faced economic challenges due to increasing competition from power plants using natural gas and renewable energy.[57] For commercial reprocessing to be economically viable, it would need to produce nuclear reactor fuel (made with reprocessed plutonium and/or uranium) at a price competitive with existing uranium fuel, or reduce nuclear plants' waste management costs. Given the economic challenges already faced by some U.S. nuclear power plants and uncertainties regarding costs of reprocessing, government policy interventions may be necessary for commercial reprocessing to be economically viable.

In 2003, a Harvard University study concluded that reprocessing "will be more expensive than direct disposal of spent fuel until the uranium price reaches over $360 per kilogram of uranium (kgU)[58]—a price that is not likely to be seen for many decades, if then."[59] Furthermore, that study argued that its findings may be conservative, as the study did not include other potential costs associated with reprocessing, such as costs for storage of separated plutonium or removal of americium, additional security, licensing and shutdown costs, and geologic disposal of spent mixed oxide (MOX) fuel.[60] The principal author of the study reiterated those findings in a 2021 presentation to the NASEM Committee on Advanced Reactors and Fuel Cycles, contending that a kilogram of plutonium fuel would cost six times as much as a kilogram of conventional uranium fuel.[61]

[56] See NASEM, *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors*, 2023, https://doi.org/10.17226/26500, p. 158.

[57] Steve Clemmer et al., *The Nuclear Power Dilemma*, Union of Concerned Scientists, 2018, https://www.ucsusa.org/sites/default/files/attach/2018/11/Nuclear-Power-Dilemma-full-report.pdf.

[58] This amount would be approximately $164 per pound. In comparison, the average uranium spot price for October 2024 was $80.50 per pound. Cameco, Uranium Price, https://www.cameco.com/invest/markets/uranium-price.

[59] Matthew Bunn et al., *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel*, Harvard University, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Final Report, 2003.

[60] For more information about MOX fuel use in the United States, see Oak Ridge National Laboratory, *The Use of MOX Fuel in the United States: Bibliography of Important Documents and Discussion of Key Issues*, ORNL/LTR - 2012/315, https://info.ornl.gov/sites/publications/files/Pub38036.pdf.

[61] Matthew Bunn, "The Economics of Reprocessing and Recycling vs. Direct Disposal of Spent Nuclear Fuel," presentation to the Committee on Advanced Reactors and Fuel Cycles of the National Academies of Sciences, Engineering, and Medicine, 2021.

Other researchers have reported costs of "closed cycles" are on average higher than "open cycles" by between less than 5% to 20%; however, they report there may be overlap in costs depending upon the various operation factors, assumptions, and uncertainties.[62]

When Congress deliberated about funding GNEP in 2008, the House Appropriations Committee expressed concern regarding the life cycle costs of the program:

> Embarking on a costly process leading to major new construction projects is unwise, particularly where there is no urgency, and the Department has failed to persuade the Committee of the critical need to proceed with GNEP now. In addition, before the Department can expect the Committee to support funding for a major new initiative, the Department must provide a complete and credible estimate of the life-cycle costs of the program [and] demonstrate that it can manage and control the costs of its ongoing projects.[63]

The 2023 NASEM study reviewed previous studies of reprocessing economics and made the following observation:

> Like all such studies, the specific methodologies vary, and there are many important assumptions made regarding the input data used to calculate costs, making cost comparisons challenging. A common conclusion reached across many cost and modeling studies is that, while spent fuel management represents a relatively small fraction of the total LCOE [levelized cost of electricity], differences in that area could result in large absolute costs depending on the size of the nuclear program and the duration of electricity generation.[64]

A more positive assessment of reprocessing economics is provided by the French nuclear fuel services company Orano, which has operated a commercial reprocessing plant at La Hague, France, since 1966. According to Orano, its costs for SNF reprocessing per mewagatt-hour of electricity generated have dropped 40% during the past 10 years. "The cost of used fuel recycling for French society represents less than 2% of the national electricity bill, or around €10 per year per household," according to the company. "This amount is going down each year thanks to increased competitiveness made possible by efficient management of industrial facilities, use of innovative processes and technologies, and optimized use of fuel in reactors." Orano further contends that the cost of reprocessing/recycling is "roughly equivalent" to that of the once-through fuel cycle.[65] The experiences of Orano may not represent those of potential reprocessing plants in the United States, due to differences in regulatory requirements among countries.

As this discussion indicates, the extent to which any reprocessing technology could be a viable, cost-effective alternative to current plans for storage and disposal of SNF would depend on a host of factors.

[62] Robin Tayler et al., "A Review of Environmental and Economic Implications of Closing the Nuclear Fuel Cycle—Part Two: Economic Impacts," *Energies*, vol. 15, no. 2472 (2022).

[63] U.S. Congress, House Committee on Appropriations, *Energy and Water Development Appropriations Bill, 2008*, committee print, 110th Cong., H.Rept. 110-185 (Washington: GPO, 2008), p. 68.

[64] See NASEM, *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors*, 2023, https://doi.org/10.17226/26500, p. 130.

[65] Orano, "All About Used Fuel Processing and Recycling," accessed January 7, 2025, https://www.orano.group/en/unpacking-nuclear/all-about-used-fuel-processing-and-recycling.

Congressional Action

Congress has enacted a variety of measures in recent years to develop advanced nuclear reactor technologies, including SNF reprocessing and recycling.[66] In the most recent example, President Biden signed the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act on July 9, 2024 (Division B of P.L. 118-870), which includes a provision to reimburse NRC licensing fees paid by the first U.S. advanced reactor that uses recycled nuclear fuel. The Energy Act of 2020 (Division Z of P.L. 116-260) authorized $60 million per year through FY2025 for DOE advanced fuel cycle research, development, demonstration, and commercial application activities, including "fuel recycling and transmutation technologies, including advanced reprocessing technologies."

Congress appropriated $322 million for all DOE fuel cycle research and development programs in FY2024, including about $45 million for Material Recovery and Waste Form Development (MRWFD), which includes reprocessing technologies.[67] For FY2025, the House Appropriations Committee recommended in report language that DOE use at least $10 million in the MRWFD program "to continue the Department's competitive, cost-shared program for reprocessing spent nuclear fuel" with the goal of commercial application by 2033.[68]

The Energy Act of 2020 also authorized $2.14 billion through FY2025 for DOE's Advanced Reactor Demonstration Program (ARDP), which includes fast neutron reactors that would be necessary for indefinite recycling of plutonium fuel. The Infrastructure Investment and Jobs Act (IIJA) authorized and appropriated $2.477 billion for ARDP through FY2025, in addition to regular annual appropriations for the program. ARDP is currently funding up to 50% of the cost of two advanced reactor demonstrations in Wyoming and Texas.[69]

Reprocessing is not currently being proposed in conjunction with the ARDP demonstration projects. If reprocessing were used to supply fuel for any of these or other commercial advanced reactor designs, the extent to which it would resolve issues discussed previously in this report would depend on a host of factors. As discussed above, these technologies would not eliminate the need to manage nuclear waste resulting from such operations.

Members of the House Energy and Commerce Committee's Subcommittee on Energy, Climate, and Grid Security expressed interest in SNF recycling as a potential element of U.S. nuclear waste management policy during an April 10, 2024, hearing on "American Nuclear Energy Expansion: Spent Fuel Policy and Innovation."[70] The Senate Energy and Natural Resources Committee held a hearing on the nuclear fuel cycle on March 9, 2023, that included discussions of reprocessing and recycling of advanced reactor fuels.[71]

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[66] For example, see the Joint Explanatory Statement (Division C for H.R. 1865) accompanying the Further Consolidated Appropriations Act, 2020 (P.L. 116-94), and §40321 of the Infrastructure Investment and Jobs Act (P.L. 117-58), and §13105 of the Inflation Reduction Act (P.L. 117-169).

[67] Energy and Water Development and Related Agencies Act, 2024, P.L. 118-42, Division D. The exact amount for Material Recovery and Waste Form Development is not specified.

[68] House Committee on Appropriations, *Report to Accompany Energy and Water Development and Related Agencies Appropriations Act*, H.Rept. 118-580, 2025, p. 112.

[69] DOE Office of Clean Energy Demonstrations, "Advanced Reactor Demonstration Projects," accessed July 11, 2024.

[70] U.S. Congress, House Committee on Energy and Commerce, Subcommittee on Energy, Climate, and Grid Security, *American Nuclear Energy Expansion: Spent Fuel Policy and Innovation*, hearing, 118th Cong., April 10, 2024.

[71] U.S. Congress, Senate Committee on Energy and Natural Resources, *Full Committee Hearing to Examine the Nuclear Fuel Cycle*, hearing, 118th Cong., March 9, 2023.

Author Information

Lance N. Larson
Analyst in Environmental Policy

Mark Holt
Specialist in Energy Policy

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