Position Statement #3

Management of the Nation's Used Nuclear Fuel and High-Level Waste

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The American Nuclear Society (ANS) supports a comprehensive approach to management of the nation's used nuclear fuel (UNF) and high-level waste (HLW). To manage this material effectively, it is essential that the federal government address various aspects of the back end of the fuel cycle, including storage, transportation, recycling, and disposal. This type of holistic strategy will engender public confidence in the nation's UNF and waste management, thereby supporting nuclear technology's valuable contributions to our nation. The strategy must also be forward-looking and flexible, so as to be prepared to address any different technological aspects of advanced reactor fuel cycles. To manage all the facets of the back end of the fuel cycle effectively, it is imperative that the federal government address key issues that have historically plagued its UNF and waste program, including governance, funding, and stakeholder support.

A comprehensive approach, as supported by ANS, includes the following elements:

- Congressional action to create a new management organization with the single responsibility of managing existing and future UNF and HLW.
- Funding for the management organization that is predictable and adequate for the tasks, and a structure that allows for flexibility and efficiency.
- The authority for the management organization to negotiate effectively with stakeholders, including communities considering hosting waste management facilities.
- A program for the disposal of UNF and HLW that includes traditional mined geological repositories as well as consideration of innovative approaches like deep borehole disposal.
- Clear statutory authorizations to establish a consolidated interim storage facility for UNF or to contract with private companies and communities for such a facility, with an initial focus on consolidating UNF from shut-down nuclear plant sites with no operating reactors.
- The continued safe transportation of radioactive materials under the current regulatory structure.
- A clear energy policy on UNF recycling and a regulatory framework that provides a transparent path to licensing recycling facilities with reduced uncertainty.
- Increased government support for research and development related to storage, packaging, processing, transportation, recycling, and disposal of advanced reactor fuel types.
- Development of waste disposal contracts for non–light water reactor fuels to enable licensing and operation of advanced reactors.
- A siting process (disposal, storage, etc.) that seeks the consent of directly affected local, state, and tribal governments through a clear, open, and transparent decision-making process.
- Updated generic Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC) geologic repository standards and regulations that will transparently ensure public health and safety.

Background Information

Management Organization

In 2010, the U.S. government formed the Blue Ribbon Commission on America's Nuclear Future (BRC) at the request of the Obama administration after funding for the Yucca Mountain Project was withdrawn. The BRC's review of the civilian nuclear fuel cycle, with a focus on waste storage and disposal, culminated with a 2012 report providing recommendations.[1] Among these seven recommendations was that the United States establish a new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed. The BRC report reasoned that the complexity of the Department of Energy (DOE)—being a large, cabinet-level agency with multiple competing missions, a budget that is dependent on annual congressional appropriations, and senior management that changes with changes in administration—has been hindered in its ability to successfully implement a nuclear waste program. In contrast, a single-purpose entity devoted solely to nuclear waste would be more efficient. The BRC was far from the first entity to recommend a different management organization structure; numerous studies and recommendations on alternative management structures date back to the Nuclear Waste Policy Act of 1982.[2,3]

In response to this recommendation, the DOE supported a study (the RAND report[4]) to examine alternative organizational models for such a new management organization (e.g., asking if the management entity should be a single-purpose government agency or a federally chartered corporation). The RAND report concluded that the organizational form is only one of many factors that would drive success of the program, and more than one design existed that could be successful. The report emphasized key considerations including the extent of presidential authority, independence from congressional oversight, and organizational structure mechanisms to instill public trust and engage stakeholders. Importantly, the report acknowledged that in addressing these considerations, decision makers would need to balance accountability with flexibility, both of which are needed to be a successful management organization. The overall message was that while the organizational structure is important, other factors may be more important to success (e.g., continuity of leadership, funding and budget control, public trust, communications, etc.).

The recommendations in both the BRC report and the RAND report suggest that a new organization that can appropriately balance accountability with flexibility could be successful. Still, in establishing the new organization, decision makers should avoid creating costly additional government bureaucracy and instead look to leverage existing infrastructure, while enhancing or rectifying the specific issues that hindered success in the past.

The BRC and RAND reports made it clear that no organizational structure would be successful if the organization did not have the necessary authorities to get the job done. Chief among those authorities is access to funding necessary to carry out the waste management mission. Money was collected from generators of nuclear electricity for the Nuclear Waste Fund, which as of 2021 had a balance of approximately $46 billion.[5] Nevertheless, funding for the DOE's Office of Civilian Radioactive Waste Management has been subject to annual congressional appropriations. The result has been very uneven year-to-year appropriations, which has hamstrung work activities and prevented effective planning. The BRC report emphasized the need to provide the management organization reasonable access to the money that was collected from generators of nuclear electricity for the sole purpose of managing and disposing of the resultant used fuel.

Interim or Consolidated Storage

The term UNF[a] refers to nuclear fuel assemblies that have been used in an operating nuclear reactor core and permanently discharged, with no intention of reinserting the assemblies back into a reactor core in their current form. Safe, secure storage of UNF is one of the many success stories of the nuclear power industry. Since 1957, U.S. nuclear power plant operators have safely stored UNF, predominantly on the reactor sites where the fuel was used.

Newly discharged UNF is stored underwater in pools at reactor sites. As these pools approach capacity limits, and once the fuel has cooled sufficiently, the UNF is transferred into robust metal-and-concrete dry storage systems, typically located on or near the reactor site in a facility commonly referred to as an independent spent fuel storage installation (ISFSI). These relatively simple and passive dry storage systems protect against events that could result in radiological releases into the environment. The ISFSIs are monitored and secured to ensure continued protection. Storage of used fuel is regulated by the NRC, the independent federal agency charged with ensuring the safe and secure use of nuclear material.

As of the end of 2021, the U.S. inventory of UNF and reprocessing waste was located at over 100 sites in 39 states. This includes nearly 90,000 metric tons heavy metal of used fuel and a small amount of vitrified HLW from commercial nuclear power plants, as well as DOE-owned used fuel and reprocessing waste from defense, research, and other activities. The U.S. nuclear industry had loaded and placed into service over 3500 dry storage systems containing approximately 155,000 assemblies since 1986.[6] The used fuel storage activities have been carried out with no adverse impacts on plant workers, the public, or the environment.

Current operational and decommissioned nuclear power plants in the U.S. were licensed with the expectation that the UNF would be stored at the nuclear power plant site for a short period of time until shipment to a recycling plant or geologic disposal facility for HLW. However, no facility capable of receiving UNF is operating in the U.S., and it is uncertain when one might become available. Therefore, utilities have been forced to store UNF at nuclear power plant sites in greater quantity and for longer time periods than originally envisioned. As longer periods of storage become inevitable, the nuclear industry and the NRC have placed an increased emphasis on assuring the long-term integrity of storage systems through aging management programs. UNF storage at nuclear power plant sites can continue to be achieved in a safe and environmentally sound manner—a conclusion supported by the successful operating

a. Used nuclear fuel is also commonly referred to as spent nuclear fuel.

experience to date as well as the NRC's Continued Storage Rule and associated environmental impact statement from 2014.[7]

Nevertheless, interim storage of UNF is a partial and temporary answer to managing the UNF produced by nuclear power reactors. Intergenerational equity and other considerations mandate that long-term storage of UNF is not a permanent solution. ANS supports the ultimate development of reprocessing, recycling, and geologic disposal. Until those technologies can be deployed on a large scale, ANS also supports the development of consolidated, away-from-reactor interim storage for UNF—in most cases using the same proven technology now deployed at reactor sites. Consolidation could result in a more efficient storage system (as aging management and security capabilities could be combined for a larger number of systems). It would also allow land that is currently being used to store UNF at decommissioned reactors to be returned to surrounding communities for other purposes. Away-from-reactor consolidated storage facilities have been safely operated for decades in Europe, using both wet (pool) storage and dry storage technology.[8] Until recycling and disposal facilities are in operation, the interim storage of UNF can continue under current controlled conditions—in pools and casks at either reactor or consolidated sites.

Fiscal year 2022 and 2023 appropriations directed the DOE to use a consent-based siting process to identify a site for a federal interim storage facility. In June 2023, the DOE issued a number of funding awards to groups of university, nonprofit (including ANS), and private-sector partners that will work with communities interested in the DOE's community-centered approach to storing and disposing of UNF.

Transportation

Transporting radioactive material is necessary to provide for the use, storage, processing, and disposal of the material. Shipments of radioactive materials on public rights-of-way are regulated by the U.S. Department of Transportation and the U.S. NRC; these regulations are effective and consistent with International Atomic Energy Agency safety standards.[9,10,11] Taken together, the experience base and the mature regulatory oversight structure provide confidence that radioactive materials have been and will continue to be transported safely.

Packages built to contain large quantities of high-activity material, such as UNF and HLW, must demonstrate their ability to withstand hypothetical accident conditions that include a high-speed impact simulated by a 30-foot drop onto an unyielding surface, 30 minutes in a completely engulfing fire at 1475°F (800°C), and immersion under 50 feet (15 meters) of water.[12]

More than 4,000 shipments of UNF have been made safely over U.S. highways and railroads since 1964.[13] Analyses demonstrate that projected shipments of UNF to a consolidated storage facility or a repository would present no additional radiological risk compared to the natural background radiation and pose no adverse impacts to the public or the environment.[14,15,16] International experience also supports this conclusion. Outside of the United States, at least 20,000 shipments of UNF and HLW have been made safely and without incident since 1962, totaling at least 80,000 tons of material.[11]

Recycling

Today's industrially proven nuclear fuel recycling involves separating the uranium and plutonium from UNF (reprocessing) and reusing these materials in the fabrication of new fuel. If used in conjunction with advanced fuel cycles and reactors, recycling has the potential to significantly enhance resource utilization by reclaiming most of the unused energy in UNF (~95 percent) and minimizing the volume of radioactive waste requiring disposal in a geologic repository. Recycling (reprocessing plus fuel fabrication) does not eliminate the need for geologic disposal but could reduce the amount of HLW requiring disposal while also avoiding the disposal of plutonium and thus significantly minimizing the long-term safeguards stewardship.

Reprocessing has been (historically at West Valley in New York) and continues to be (now at H-Canyon at the Savannah River Site in South Carolina) performed in the U.S. safely and securely. Frequently identified concerns related to recycling include cost, proliferation, regulatory gaps, impact of used mixed oxide fuel, produced quantities of wastes, and treatment of off-gases (per 40 CFR 190).[17] Proliferation concerns are addressed through regulations (e.g., 10 CFR 73 and 10 CFR 74 address physical security and materials control and accountability, respectively).[18,19] Other concerns are currently being addressed through programs such as the Advanced Research Projects Agency–Energy (ARPA-E) ONWARDS and CURIE programs.[20]

Continued R&D of nuclear fuel recycling without a policy and plan for deployment will not make the technology a practical reality. Instead, there is the opportunity to tie development of advanced reactors to developing fuel recycling options to minimize the application of the once-through fuel cycle. Many advanced reactor systems currently under development are specifically designed to take advantage of the energy value that exists in our current reserves of UNF. However, our country lacks an efficient, technically robust, and technology-inclusive regulatory framework for reprocessing and recycling, which is serving as a barrier to innovation.

The NRC had been involved in rulemaking-related activities connected to reprocessing since the early 2000s. In 2013, the NRC started development of a reprocessing-specific rule as a new part of the NRC regulations. In 2016, the NRC suspended work on the rulemaking due to budgetary constraints and an apparent lack of commercial interest in constructing and operating a spent fuel reprocessing facility. The regulator abandoned completion of its rulemaking for recycling in 2021, and ANS noted in a letter to the NRC[21] dated May 28, 2020, that ANS supports a resumption of NRC action on its spent fuel reprocessing rulemaking to address regulatory gaps that would tangibly reduce the regulatory uncertainty associated with deploying reprocessing technologies, thereby lowering the costs and risks of deployment.

Geologic Disposal

Deep geologic disposal will be needed no matter which fuel cycles are used. The amount and composition of the waste streams destined for disposal will vary between fuel cycles, but there will always be at least some waste requiring deep geologic disposal. Geologic disposal can be in either traditional "mined" geologic repositories or potentially in deep boreholes.

The 1982 Nuclear Waste Policy Act (NWPA) and its amendments directed the DOE to take the following actions:

- Site, develop, license, operate, and close two geologic disposal sites for the entire inventory of commercial and defense-related spent nuclear fuel and high-level radioactive wastes.
- Take title to and remove used commercial nuclear fuel from existing storage sites now in thirty-five states.

The site at Yucca Mountain, Nevada, has been designated by Congress to be developed by the DOE for disposal of commercial spent nuclear fuel and defense wastes. As of 2023, Congress has neither changed this designation nor directed the DOE and the NRC to cease the licensing process. However, it has been well over a decade since Congress has provided funding to proceed any further through the Yucca Mountain licensing process. Furthermore, per the original 1982 NWPA, two disposal sites were to have been constructed with the first repository receipt capacity administratively limited to 70,000 MTU (or equivalent reprocessed HLW) until a second repository starts operation. This legal capacity limit was roughly half of the total amount of projected spent nuclear fuel to be generated by commercial nuclear power plants. It is estimated that roughly 144,000 MTU will be generated by the existing nuclear plants by the end of their lives.[6] However, in 1987, Congress canceled the development of the second site.

Without future congressional action, there remains no effort toward geologic disposal in the United States at present. Spent nuclear fuel continues to be stored at the reactor sites pending the DOE taking title to and removing the spent fuel as required by the same 1982 NWPA. This steadily growing inventory of spent fuel demands government action on geologic disposal. ANS Position Statement #80, "Licensing of Yucca Mountain as a Geological Repository for Used Nuclear Fuel and High-Level Radioactive Waste," states that ANS "supports the expeditious processing of the Yucca Mountain geologic repository license application in an open, technically sound manner."[22] However, even if Congress elects to fund the remainder of the Yucca Mountain licensing process and Yucca Mountain is constructed and operated, at least one additional, large disposal site is legally required. If the NWPA statutory administrative limits were changed to allow a single repository to accommodate all of the nation's UNF, or its corresponding wastes from reprocessing, there could be value from large-scale implementation of advanced fuel cycle(s) that reduce the volume and toxicity of waste requiring deep geologic disposal.

An initial step that Congress needs to take is to require and fund the development of an updated generic geologic disposal standard. This action has been requested by many organizations, such as the BRC and ANS. To kickstart the development of a new generic disposal standard for Congress and the U.S. EPA to consider, ANS established a Special Committee on Generic Standards for Disposal of High-Level Radioactive Waste. In February 2023, the ANS Special Committee released a draft report with recommendations for updated standards for the permanent disposal of spent nuclear fuel and HLW at future geologic repository projects in the United States.[23] The draft report aims to update the current U.S. geologic repository standards that are codified in the EPA regulation 40 CFR Part 191[24] and apply to all sites except Yucca Mountain in Nevada and the Waste Isolation Pilot Project in New Mexico.[23]

One of the many lessons learned during the development of the Yucca Mountain site prior to and during the initial licensing process is that the lack of consistent, adequate congressional funding resulted in higher costs as the DOE had to scale back or delay key projects, ramp them up again in years when adequate funding was available, then scale back or delay projects again as Congress provided inadequate funding in other years. The existence of approximately $46 billion in the Nuclear Waste Fund[5] should be adequate for the DOE to proceed with Yucca Mountain licensing along with at least some other projects for the DOE to complete the actions Congress set out for the DOE in the 1982 NWPA and amendments.

Advanced Reactors

Advanced reactors are expected to play an important role in meeting our country's current and future energy needs. Advanced reactors often use fuel types different from conventional low-enriched uranium oxide—such as high-assay low-enriched uranium, mixed uranium-plutonium, or thorium-based fuels—and generally incorporate coolants such as liquid metal, gas, or molten salt. Advanced reactor designs offer the benefits of current reactors and may enable fission technology to extend beyond clean electricity production. The higher operating temperatures of many advanced non–light water reactor designs enable clean, carbon-free, and economical process heat applications, providing an alternative to the fossil fuels that are currently used for these applications. ANS Position Statement #35, "Advanced Reactors,"[25] provides additional information in this area.

The fundamental goal of managing used fuel and HLW is ensuring that the radioactive materials (fission products and actinides) do not adversely affect people and the environment. That goal is the same for advanced reactors as it is for current light water reactors. The physical characteristics of advanced reactor used fuels are somewhat different from light water reactor fuel, and the experience base is in some cases less substantial. However, there is every reason to expect that existing light water reactor storage and transportation technologies, modified as appropriate, can be applied with the same level of success to advanced reactor fuels. Similarly, technologies for disposal of light water reactor fuel and recycling products appear to be adaptable for disposal of advanced reactor used fuels and recycling byproducts, as well.

For some advanced reactor designs, the physical characteristics of the fuel may offer advantages relative to light water reactor fuel when it comes to storage, transportation, and disposal. For example, a number of developers plan to use TRIstructural ISOtropic (TRISO) fuel particles, which have been shown to retain fission products effectively, even at very high temperatures. Some advanced reactor developers plan to eventually recycle the used fuel and reuse the fissile material, potentially reducing the amount of waste and impacting the characteristics thereof. Recycling operations require resources, and for light water reactors the costs generally outweigh the value of the recovered material at current uranium, conversion, and enrichment prices. Proposed fast spectrum reactors are neutronically better suited than thermal reactors for the utilization of actinide isotopes as fuel, though significant development remains to be done.

The 2023 National Academies of Sciences, Engineering, and Medicine report *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors*[26] addresses radioactive waste issues associated with advanced reactors. The report identifies no insurmountable obstacles in the waste management area, but it notes the need for research and development in the back end of advanced reactor fuel cycles.

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