U.S. Spent Nuclear Fuel Policy: The Current Stalemate and Policies to Generate Momentum and Support Advanced Reactor Investment

Matt Bowen
Senior Research Scholar, Center on Global Energy Policy at Columbia University

October 2023

This research paper was commissioned by the EFI Foundation (EFI) and represents the views and conclusions of the author(s).

EFI has not endorsed or approved the statements and conclusions contained in these documents but will be sharing this work as part of the project process.

EFI FOUNDATION

ENERGY FUTURES FINANCE FORUM

900 17th Street NW, Suite 1100, Washington, DC 20006

About the Author

Dr. Matt Bowen, PhD

Dr. Matt Bowen is a Senior Research Scholar at the Center on Global Energy Policy at Columbia University SIPA, focusing on nuclear energy, waste, and nonproliferation. He is also a nonresident senior fellow with the Atlantic Council's Global Energy Center. He was formerly a Nuclear Policy Fellow at Clean Air Task Force and a Senior Policy Fellow at the Nuclear Innovation Alliance.

Dr. Bowen has written reports on federal and state policies to encourage advanced reactor development and has also published papers on reforming U.S. nuclear export controls. During the Obama Administration, he was an Associate Deputy Assistant Secretary in the Office of Nuclear Energy and a Senior Advisor in the Office of Nonproliferation and Arms Control at the U.S. Department of Energy (DOE). Previous to working at DOE, he was an AAAS/APS Science Fellow for Senate Majority Leader Harry Reid.

Dr. Bowen received a Bachelor of Science degree in physics from Brown University and a Ph.D. in theoretical physics from the University of Washington, Seattle. He has held positions at the National Academies with the Board on Physics and Astronomy, the Board on Energy and Environmental Studies, and the Division on Engineering and Physical Sciences. Dr. Bowen has also done work outside of Columbia University as an independent consultant for Energy Futures Initiative and Third Way.

Report Sponsors

The Energy Futures Finance Forum would like to thank the following sponsors of this report:

JPMorgan Chase & Co.

The Cynthia & George Mitchell Foundation

Ray Rothrock

EFI Foundation (EFI) advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, EFI conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI maintains editorial independence from its public and private sponsors.

Table of Contents

1. Introduction

The purpose of this paper is to discuss nuclear waste management issues as they might affect deployment of the next generation of advanced reactors, including small modular reactors (SMRs). Advanced reactor developers promise greater inherent safety to their designs and potential cost reductions compared with the previous generation of reactors. In many cases, their spent fuel and associated waste management challenges will differ substantially from the spent nuclear fuel (SNF) produced by the existing fleet of U.S. nuclear power plants, which are exclusively comprised of light water reactors (LWRs).

Some of the new advanced reactor fuels under development could result in changes to the amounts (mass or volume) of SNF to be disposed of, the chemical composition of SNF, and the specific radionuclide inventories involved, as compared with current LWR SNF. Advanced reactor SNF could also present different thermal power outputs and might have differing durability in various disposal environments as compared with LWR SNF. All of these factors have implications for storage and disposal of SNF in terms of increasing or decreasing certain challenges. In general, most of the advanced reactor designs under development would generate waste streams for which there is little experience in the U.S., and potentially anywhere worldwide. The technical differences support a rationale for potentially distinguishing legacy SNF from new SNF produced by many of the different advanced reactor designs. Existing LWRs and likely most, if not all, advanced reactors will also produce some amount of greater-than-class C (GTCC) nuclear waste. Like commercial SNF, this is an inventory that lacks a disposal pathway, but is, in general, less radioactive than commercial SNF.

In the absence of an operating geologic repository for commercial SNF disposal, U.S. efforts in recent years have focused on consolidated interim storage – in particular for shutdown nuclear power plants where SNF remains. Private entities obtained licenses from the U.S. Nuclear Regulatory Commission (NRC) to build and operate such facilities in New Mexico and Texas, but the two States oppose the respective projects, and, in August 2023, a federal court ruled that the NRC does not have the legal authority to issue license to private entities to store commercial SNF away from reactor sites. Congress directed DOE in Fiscal Year 2021 to start a federal, consent-based siting program for consolidated interim storage, though its fate is unclear in the absence of other improvements to the broader U.S. nuclear waste management program.

Responding to this context, advanced reactor designers have generally proposed to have enough storage space on-site to accommodate spent fuel generation over the full course of the reactor lifetime. As discussed later in this paper, it may be possible that a new or modified spent fuel regime could be created that would establish an initial framework for spent fuel management that would help enable new advanced reactor deployments. It is also possible, however, that it may turn out that the issue of legacy SNF has to be resolved or improved in tandem with any new plan for spent fuel from advanced reactors; thus, both inventories will have to be addressed at the same time.

Section 1 of this paper covers in brief developments in U.S. SNF management policy from 1982 to the current stalemate that the U.S. program has reached in 2023. In Section 2, the high-level recommendations from the 2012 Blue Ribbon Commission on America's Nuclear Future (BRC) are reviewed, along with their implementation status as of mid-2023. [1] The BRC recommendations form the basis for subsequent discussion in the paper on policy options to move the U.S. program forward. Section 3 looks at the spent fuel that various advanced reactor designs would produce, and how it compares with the spent fuel from the existing LWR fleet, along with implications for spent fuel management and disposal. Finally, Section 4 examines four nuclear waste policy topics in greater detail**:** creating dedicated trust or escrow accounts in lieu of payments to the Nuclear Waste Fund (NWF) for future advanced reactors; establishing a dedicated office at the U.S. Department of Energy (DOE) for implementing the federal SNF and HLW management program; considering regional approaches to consolidated interim storage; and establishing a GTCC nuclear waste disposal capability. As explained later, this last area may be a good one for U.S. policymakers to focus on to generate some momentum for the U.S. nuclear waste disposal program and build confidence and capacity as the U.S. restructures its approach to SNF management.

2. The Current Stalemate

The U.S. first began producing SNF and high-level nuclear waste (HLW) in significant amounts as part of its nuclear weapons programs dating back to the Manhattan project in World War II. The advent of power reactors on the U.S. electrical grid a little over a decade later meant the beginnings of commercial SNF generation.

While the Atomic Energy Commission took some actions in subsequent decades related to U.S. SNF and HLW disposition (other references cover these earlier efforts) this white paper begins its brief historical overview with the passage of the Nuclear Waste Policy Act of 1982 (NWPA). [2] The NWPA is still the law that governs U.S. SNF and HLW management, including any potential development of federal consolidated interim storage facilities (CISF) for commercial SNF as well as deep geologic repositories for HLW and SNF. As such, a brief history of its implementation is provided in this section.[a]

A central compromise that enabled passage of the NWPA was that the Executive Branch would recommend two repository sites to Congress: the first by March 31, 1987 and the second by March 31, 1990. The rationales for requiring two sites including reasons of geographical equity, minimizing the impacts and cost of transportation, and not having a single state bear the full burden of disposing of all of the nation's SNF and HLW. While it was not specifically written into the NWPA, it was widely understood that the first repository would be in the west and the second in the east. The NWPA included a cap of 70,000 metric tons of SNF on the first repository until the second repository was in operation and created the Office of Civilian Radioactive Waste Management to carry out the federal program from within the U.S. Department of Energy.

The Act authorized DOE to enter into contracts with the owners of nuclear power plants for acceptance of SNF, subsequent transportation, and disposal. In exchange for the federal

[a] This brief history can be found in more detail in references such as Walker 2009; BRC 2012; Matt Bowen, "Forging a Path Forward on Nuclear Waste Management: Options for Policy Makers," January 28, 2021. https://www.energypolicy.columbia.edu/publications/forging-path-forward-us-nuclear-waste-management-options-policy-makers/

government taking responsibility for the SNF their reactors generated, the utilities would begin paying 0.1 cents per kilowatt-hour (kWh) of electricity generated by the reactors into a new Nuclear Waste Fund (NWF), which was intended to cover the costs of the program. The Act required DOE to review the adequacy of the fee to pay for the full lifetime costs of the program, and to propose an adjustment to the fee if necessary to ensure that full cost recovery. In 1983, the DOE entered into 76 such contracts with various entities.[3] The NWPA required that the contracts would provide that the Secretary of Energy would dispose of the HLW or SNF beginning not later than January 31, 1998, in exchange for the payment of fees.

However, the original structure of the NWPA was undone just a few years later. In January of 1986, DOE announced preliminary rankings of rock formations in seven states in the eastern part of the United States for the second repository. The announcement provoked a strong public outcry in those seven states in particular and only four months later, the Secretary of Energy announced that the second repository program was being deferred indefinitely. The Reagan Administration portrayed the suspension of the second repository program as being due to lower projections of nuclear power growth, but it was broadly perceived as the Administration bending to political pressure from eastern states. Members of Congress from western states decried the move and warned that the Administration had unraveled a key compromise the enabled the NWPA to pass into law in the first place.

At the same press conference where Secretary of Energy John Herrington announced the suspension of the second repository program, he also announced that the candidate sites for the first repository had been narrowed to three: Yucca Mountain in Nevada, Deaf Smith County in Texas, and Hanford in Washington. Given the suspension of the second repository program, these states were then faced with the prospect of being the sole repository identified for development and as a result potentially being forced to dispose of all of the nation's SNF and HLW. Western members of Congress openly worried that a later Congress might simply lift the 70,000 metric tons cap on the first repository when it was politically expedient to do so – making the site an open-ended disposal facility.

In the Omnibus bill of 1987, conferees of the House and Senate bills added new language to the funding bill that would dramatically reshape the U.S. SNF and HLW program. The text that the 1987 Omnibus conferees came up with (Subtitle E, "Redirection of the Nuclear Waste

Program Selection of Yucca Mountain Site") terminated all site-specific activities at all candidate sites other than Yucca Mountain in Nevada. The amendments directed the Secretary of Energy to carry out site characterization activities at Yucca Mountain and deleted the requirement that the President submit to Congress a recommendation of a second repository site by March 31, 1990. Instead, site-specific activities with respect to a second repository were prohibited without specific authorization from Congress.

Quickly dubbed the "Screw Nevada Bill" in Nevada, the amendments to the NWPA that came from the 1987 Omnibus bill helped to solidify opposition in the state against the project.[4] The bill text being created in secret and the House Speaker and House Majority Leader were from the other two states that were candidates to potentially host the first repository contributed to the public perception in Nevada that the state's relatively weak political position had determined the outcome.

After over a decade of site characterization work at Yucca Mountain, President Bush formally recommended the site to Congress in 2002, as was required by the NWPA before moving to licensing and construction. According to provisions in the Act, after the site recommendation from the president, the Governor of Nevada was allowed to submit a notice of disapproval regarding the project, which Governor Kenny Guinn did shortly thereafter. In the event of such a notice of disapproval, the Act required both chambers of Congress to then vote on whether to approve the site, and H.J. Res.87 and S.J.Res.34 were both passed by the House and Senate, respectively, formally approving the site later in 2002. In 2008, a license application for the construction of a repository at Yucca Mountain was submitted by DOE to the NRC.

Several developments in the political world, however, were to then upend the Yucca Mountain project. Senator Harry Reid – who was first elected to the Senate in 1986, just before the "Screw Nevada Bill" – became leader of the Democratic caucus in 2004 following Senator Tom Daschle's re-election bid. Senator Reid later successfully pushed for Nevada to become the third state in the nation to vote for presidential nominees, effectively nationalizing Yucca Mountain as a policy topic to be addressed by prospective presidential aspirants starting with the 2008 presidential contest.[5] In 2007, Harry Reid became the Senate Majority Leader and appropriations for the nuclear waste program – which had already been in decline since 2005 – were subsequently reduced even further.[b]

During his presidential campaign, then-Senator Barack Obama had voiced opposition to the Yucca Mountain project.[6] Not long after his election, in 2010, DOE moved to withdraw the license application that had been submitted to the NRC to construct Yucca Mountain and eliminated the Office of Civilian Radioactive Waste Management. DOE did not request any funding to move Yucca Mountain forward in Fiscal Year 2011, nor did it request money for the same purpose in any of the later years of the Obama Administration. In parallel, Congress did not appropriate any money to move the Yucca Mountain project forward following 2010.

In 2013, a federal court decided that the utilities need not pay fees into the NWF due to the defunct status of the federal nuclear waste management program. Specifically, the court ordered the Secretary of Energy to “change the fee to zero until such a time as either the Secretary chooses to comply with the Act as it is currently written, or until Congress enacts an alternative waste management plan.”[7] Accordingly, in 2014, DOE stopped collecting the fees from utilities.[8]

In 2017, the Trump Administration reinstated a budget request for the Yucca Mountain project, and also did so in the two presidential budget requests that followed. Congress did not appropriate money in response to any of them, however. In 2020, a presidential election year, President Trump announced a turnaround on Yucca Mountain and did not request any money for the project in the fiscal year 2021 request.[9] In all of the Trump Administration years, however, Congress never appropriated any money to move the project forward.

During the subsequent Biden Administration, officials have stated that the Administration will not try to force Yucca Mountain against Nevada’s will and there has been no request for any money to move the Yucca Mountain project forward in any of its budget requests. Congress has also not appropriated any money to move the Yucca Mountain project forward during the Biden Administration years.

---

[b] Figure 17 on page 72 of BRC 2012 shows a chart of appropriations for the nuclear waste program.

In 2021, there were about 86,000 metric tons of commercial SNF in the United States, increasing by about 2,000 metric tons each year. While the 1987 amendments to the NWPA designated Yucca Mountain as the only site for characterization, and indefinitely deferred the second repository program, they did not lift the 70,000 metric ton cap on the first repository and instead required DOE to provide a Report to Congress between 2007 and 2010 on the need for a second repository. DOE issued the requisite report in 2008 which assessed that if the cap was not lifted, the nation would need a second repository.[10]

3. The 2012 Blue Ribbon Commission Report Recommendations and Current Implementation Status

When the Obama Administration moved to terminate the Yucca Mountain program, it also announced the formation of a Blue Ribbon Commission to study and make recommendations on a way forward for the U.S. nuclear waste program. The BRC published its report in 2012 and the eight high-level recommendations from the Executive Summary and their implementation status are reviewed in Table 1.

Table 1: BRC recommendations and status[11]

BRC Recommendation	Current Status
A New Consent-Based Approach to Siting	Some progress. Congress appropriated money in Fiscal Year 2021 and directed DOE to begin a consent-based siting process for a consolidated interim storage facility (CISF), but not for disposal facilities. DOE awarded money in 2023 to groups to provide engagement and training resources for communities interested in learning more about interim storage, but it not currently soliciting volunteer communities.[12] Congress has not amended the NWPA, however, which still precludes DOE from constructing such a facility until a repository developed under the NWPA has been issued a construction license by the NRC.
A New Organization to Implement the Waste Management Program	No progress. Legislation has been introduced that would create a new entity and congressional hearings have referenced the topic and discussed it, but no committee has voted to advance the legislation, and no Chamber has passed such a bill. DOE continues to have responsibility for implementation of the U.S. SNF management program.
Access to Utility Waste Disposal Fees for their Intended Purpose	No progress. Collection of the fees that utilities paid into the NWF was also stopped by DOE in 2014 in response to a court decision.
Prompt Efforts to Develop a New Geologic Disposal Facility	No progress. The Obama Administration had begun preparatory work to initiate a consent-based siting process to develop a new repository (or repositories) including the possibility of a defense waste only repository, but the Trump Administration

	halted these efforts and they have not resumed in the Biden Administration.
Prompt Efforts to Develop One or More Consolidated Interim Storage Facilities	Some progress. As mentioned above, Congress has recently directed DOE to begin a consent-based siting process for a consolidated interim storage facility using existing statutory authority. Separate from federal efforts, private entities in New Mexico and Texas had applied for and received licenses from the NRC for to operate consolidated interim storage facilities that would not be government owned. However, both projects are opposed by their respective states, do not appear to be moving forward, and a federal court ruled that the NRC did not have the authority to issue a license for private storage away from reactor sites.
Early Preparation for the Eventual Large-Scale Transport of Spent Nuclear Fuel and High-Level Waste to Consolidated Storage and Disposal Facilities	Some progress. DOE has made progress on the development of, for example, a railcar for transporting SNF and analyzing the status of transportation capabilities at shutdown sites.[13,14,15] Other actions recommended under this broader topic have not been acted on, such as expanding the authorities and responsibilities in Section 180(c) of the NWPA.
Support for Advances in Nuclear Energy Technology and for Workforce Development	Substantial progress. The DOE and Congress have made large investments (i.e., greater than $5 billion) in advanced reactor development and front end of the nuclear fuel cycle capabilities. The NRC, at the direction of Congress, has also begun a new rulemaking aimed at licensing advanced reactors.
Active U.S. Leadership in International Efforts to Address Safety, Non-Proliferation, and Security Concerns	Some progress. There has been no progress on supporting multinational enrichment and reprocessing facilities or on spent fuel takeaway arrangements. The National Academies did conduct a study on lessons learned from Fukushima accident.

Source: Blue Ribbon Commission, 2012

Ironically, while the BRC was chartered to help the nation make progress on the back end of the fuel cycle, its recommendations on advanced nuclear energy development are the ones that have seen the most progress. On key recommendations, including creating a new organization to implement the waste program, fixing the funding structure of the program, and prompt efforts to develop a new geologic repository, there has been no progress. In some areas, the nation has arguably moved backwards, such as the stopping of fee collection for the NWF in 2014. Finally, Congress has directed DOE to take steps towards a consent-based siting program for consolidated interim storage facilities, though whether those efforts will be successful in the absence of acting upon other BRC recommendations (e.g., on a disposal program) remains to be seen.

In the last chapter of the BRC report, the Commission recommended a list of near-term actions. Some of the recommendations still have not been acted upon, including:

- DOE has not negotiated new contracts with contract holders to provide a new payment option (technically, the recommendation was that DOE “offer” to enter into such negotiations—an action that, if it occurred, may not be known to the public).
- The receipts from the nuclear waste fee have not been reclassified as discretionary offsetting collections and allowed to be used to offset appropriations for the waste program.
- DOE did develop a plan for taking the borehole disposal concept to demonstration, however the program ran aground after a specific team was selected and opposition grew in the Dakotas region (even though the demonstration would not have involved any nuclear material).
- The U.S. Environmental Protection Agency (EPA) and NRC have not worked together to define an appropriate process for developing a generic safety standard for geologic disposal sites, nor have they received direction from Congress to do so.

All of these would be helpful steps towards giving the U.S. SNF and HLW program momentum. The last bullet in particular could be a timely step, given the consent-based siting efforts mentioned above. Without a federal program on establishing a disposal capability, states considering consolidated interim storage facilities will understandably worry that they will end up being long-term facilities. Since the EPA standards that will apply to a new deep geologic repository need to be done early in the siting process – as the BRC recommended – the earlier this effort can be started, the better. At the very least, EPA working on new standards would show states considering consolidated interim storage facilities that the federal government is taking some action related to disposal.

4. Advanced Reactor Development

While the U.S. SNF management program has reached the stalemate described earlier, a wide variety of advanced reactor concepts are now under development, some with SNF that departs in significant ways from the LWRs that comprise all of US nuclear plant capacity. Most reactors under development are smaller than the previous generation of gigawatt-class reactors and instead have electrical outputs of less than 300 MWe. For reactor developers that plan to utilize modular construction techniques, these smaller reactors have been termed "small modular reactors" (SMRs) and some have much smaller outputs, including the so-called "micro-reactors" (i.e., typically with outputs between 1 and 10 MWe).[16] The classes of reactor technologies under development (usually named by the coolant they use) include LWRs, high temperature gas reactors (HTGRs), sodium fast reactors (SFRs), fluoride high temperature reactors (FHRs), and liquid-fueled molten salt reactors (MSRs). Some designs under development might be commercially available at the end of the 2020s, while others might take decades longer to reach commercialization. A 2023 National Academies study "Laying the Foundation for New and Advanced Nuclear Reactors in the United States," assessed that the commercialization time frame for some reactor designs was the mid-2030s at the earliest, and that this timeline was only possible if several identified challenges in the report were addressed.[17]

From a spent fuel point of view, the light water SMRs such as NuScale Power's VOYGR and GE-Hitachi's BWRX-300 will utilize fuel designs that differ in relatively small and straightforward ways (e.g., the length of the fuel assemblies may be shorter) from the LWR fuel already in use by existing U.S. reactors. LWR fuel makes up the vast majority of the legacy U.S. commercial SNF inventory, and all of the roughly 2,000 metric tons of SNF that is currently produced each year in the United States comes from LWRs. The fuel rods are approximately 12 to 14 feet tall that make up LWR fuel assemblies.[c]

[c] See page 10 of BRC 2012 for a description of LWR fuel assemblies.

However, other reactors designs will produce spent fuel with different – some very different – characteristics as compared to LWR fuel. A 2023 National Academies (NAS) study, “Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors,” forms much of the basis for the discussions below.[18] NAS 2023 noted that the new advanced reactor fuels under development could result in changes to the amounts (mass or volume) of SNF to be disposed of, its chemical compositions, and the specific radionuclide inventories. The SNF could also present different thermal power outputs and might have differing durability in a given disposal environment. NAS observed that most of the advanced reactors under development would generate waste streams for which there is little experience in the U.S. and potentially anywhere worldwide. In cases where additional waste treatment options are considered after SNF has been produced, these would entail additional costs not encountered in LWR SNF management.

One difference is that enrichment levels for HTGR, FHR, and SFR fuels are expected to be higher than the current 3-5% levels of Uranium-235 in LWR fuel. Instead, new high-assay, low-enriched uranium (HALEU) in the range of 15 to 19.75% will be utilized. Russia had been the sole commercial source of HALEU, but in light of the Russian invasion of Ukraine, the U.S. Congress, as part of the Inflation Reduction Act, set aside $700 million to support development of a domestic source of HALEU. [19] A general technical aspect of these higher enrichments is that the resulting SNF is expected to reach higher burnups than LWR fuel.

Another generic aspect of non-LWRs is that they typically operate at higher temperatures than LWRs (e.g. at 600°C instead of 300°C), which enables greater efficiencies in converting heat to electricity, leading to less fission products produced per megawatt-hour (MWh) generated.

Some additional examples (both advantages and disadvantages) of how non-LWR fuel can differ from LWR are provided below, though this is by no means a comprehensive list.

Fast reactors. The most common type of fast reactor under development are those that use sodium as a coolant. SFRs use fuel rods that are in some ways similar to the fuel rods in LWRs. However, SFR fuel rods may be made out of different materials, such as stainless steel, as opposed to the zirconium-alloys used in LWR fuel claddings, and the fuel may be in metallic form as opposed to ceramics. Additionally, the fuel rods may also have sodium inside the cladding (i.e., “sodium-bonded fuel”) which is not the case with LWR fuel.

Fast reactor spent fuel should have reduced production of Plutonium-241 (compared with LWR fuel on a per MWh basis) as its production is inhibited in a fast neutron spectrum compared with thermal spectrum neutrons in an LWR. This is a waste management benefit since Pu-241 decays to Am-241, which is a leading contributor to heat production in a repository environment and thus determines to some degree of separation of waste package requirements and mining needs (which have cost implications). If fast reactors are paired with separations technologies (i.e. reprocessing) to separate out a portion of the actinides in the SNF to be fabricated into fuel that goes back into the reactor, the overall actinide content (including plutonium) headed to a repository would be – over the lifetime of the reactor – even lower on a per MWh basis than LWR fuel. At least one developer, Oklo, plans to utilize reprocessing.[20]

On the other hand, as NAS 2023 noted, sodium fast reactors will produce large volumes of irradiated sodium waste requiring treatment and disposal.[21] Moreover, if the fuel rods for SFRs have sodium inside of them, this is the one type of SNF in the current US legacy inventory that the DOE national laboratories have determined is not generally suitable for direct disposal, and could thus require treatment by processes that are not yet mature at an industrial scale.[22] A 2017 Nuclear Waste Technical Review Board report noted that since 1996, DOE had only treated less than 10% of the 5.57 metric tons of heavy metal of sodium-bonded SNF awaiting treatment at Idaho National Laboratory.[23] NAS 2023 also noted that all fast spectrum reactors will use components (e.g. reflectors and shielding) that will become irradiated and contaminated and require disposal as GTCC nuclear waste in the United States.

HTGRs and FHRs. The fuels for HTGRs and FHRs are a greater departure from that of LWRs as compared with SFRs. Instead of fuel rods, HTGRs and FHRs may use hundreds of thousands of small (roughly 3 to 6 centimeters in diameter) graphite balls that each have thousands of millimeter-sized coated fuel particles inside of them.[24]

The fuel form (including the silicon carbide coating layers) may act as an additional barrier inside a geologic repository or deep borehole, contributing positively to the safety case by restraining the movement of radionuclides. According to NAS 2023, however, more research is needed to demonstrate this adequately.[25]

NAS 2023 also noted that these reactors will produce a much larger volume of SNF compared with LWR SNF on a per MWh basis on account of the graphite pebble form. If it becomes desirable to reduce the volume of irradiated graphite in HTGR and FHR SNF that is headed to a repository, however, the technologies to accomplish this are currently immature.

Liquid-fueled MSRs. In the biggest departure from current fuel forms, liquid-fueled MSRs use various salts (e.g. LiF-BeF_2) as a coolant with the fuel mixed in. The liquid fuel is continually processed (i.e. some elements are removed, primarily fission products) during operations. This waste output will have to be safely managed, as well as the remaining fission products and actinides generated as part of reactor operation, which are spread throughout the coolant. As NAS 2023 notes, this presents some novel issues for the spent fuel salt waste, which would require processing to produce waste forms suitable for disposal. The Committee assessed that further R&D was needed, in particular, on the processing of chloride and fluoride salts required to generate suitable waste forms.[26]

The 2012 BRC report included calculations of some of the waste management advantages and disadvantages to several nuclear fuel cycles that differed from the once through LWR approach.[27] As one example that is consistent with the statements above, the BRC calculated that HTGRs would produce a ten times increase in SNF volume going to a repository as compared to a LWR cycle for the same amount of energy, but an HTGR fuel cycle would actually lead to a 25% reduction in repository space requirements given the higher reactor efficiency.

To take a second example, the BRC also examined a fast-spectrum, liquid-metal-cooled reactor system utilizing a closed fuel cycle (i.e., employing recycling). The report noted the possibility of tailored waste forms for the separated fission products, and the potential for a reduction in long-term repository dose from TRU elements if recycling was sustained for decades to centuries. The BRC calculated that this fuel cycle might lead to a 40% increase in waste volume headed to a repository, but it would reduce near surface wastes (primarily due to mill tailings and depleted uranium) by 95%, reduce certain low-level wastes associated with the front end of the fuel cycle, and overall decrease repository space required by 75% as compared with a once-through LWR cycle.

Overall, the BRC examined other aspects of these fuel cycles as well (safety, cost, sustainability, non-proliferation, and counterterrorism) and concluded that there were no clear winners among the main alternative fuel cycles analyzed. But there are obviously substantial differences from a waste management point of view to the different possibilities, with implications for SNF treatment, transportation, and repository needs. The differences described above support a technical rationale for distinguishing legacy SNF from new SNF produced by most of the future advanced reactors.

Another SNF-related difference between the legacy fleet and new advanced reactors concerns the contract between the federal government and utilities over the spent fuel. The NWPA of 1982 made SNF management a federal responsibility. Section 302 of the NWPA does not allow the NRC to issue a new license for a power reactor unless the entity involved has entered into a contract with the federal government under that section for the SNF. New reactors will be using an amended version of the "standard contract" that is different from the contracts that were signed when the legacy fleet was first licensed.

The amended standard contract no longer mentions the January 31, 1998, date as when DOE services will be provided by – the original plan in the NWPA – but instead states that DOE will begin acceptance of any SNF from a nuclear power reactor no earlier than 20 years from the initial discharge of SNF from that reactor. [d] The amended contract states that DOE will complete acceptance of all SNF from a power reactor no later than a defined "performance date," which is defined to be ten years after the expiration of the operating license granted by the NRC for the facility (as extended or not). The government's liability for delays in delivering these services, however, is substantially limited in the amended standard contract. Damages are only available if DOE does not accept all SNF by the performance date, and the damages are defined to be $5 million per year (on January 1, 2008 dollars, adjusted for inflation). A new clause would appear to limit DOE's liability for delays if they are the result of action or inaction

[d] The amended standard contract for new reactors can be found at: https://www.energy.gov/gc/articles/standard-contract-amendment-new-reactors

by Congress.[e] It could be reasoned then, that if Congress does not authorize, require, or provide funding for a program that would support DOE removing SNF from a contract holder's power plant site by the defined performance date, the federal government may have very little liability.

Especially given the stalemate that the U.S. SNF management program has reached, advanced reactor companies will have to plan for, design, and construct storage facilities for spent fuel, which the NRC will regulate. For example, some reactor plants have been designed so that they can store all of the SNF generated during the course of their operating lifetime onsite.[28] Whenever the SNF is transported to another location (e.g. a disposal facility) the existing regulatory structure appears able to accommodate the associated review and licensing of these efforts, though work may be needed in some areas to demonstrate compliance with regulatory criteria.[29]

Apart from technical, financial, and regulatory challenges associated with spent fuel management, advanced reactors also face a social license challenge without a healthy U.S. SNF management program that is making progress. Some states have laws in place that prohibit the deployment of new reactors without progress in the U.S. SNF management program.[30] There will also be inevitable questions on waste management planning from state and local communities considering hosting new advanced reactors.

For all of these reasons, it would be helpful to advance reactor deployment for U.S. policymakers to invest resources into improving the position of the U.S. SNF management program, including action on some of the BRC recommendations reviewed earlier that have not been acted upon. The next section highlights some specific policy topics in this regard.

---

[e] From the amended standard contract: "In the event circumstances beyond the reasonable control of the Purchaser or DOE – such as acts of God, or of the public enemy, acts of Government in either its sovereign or contractual capacity (including, but not limited to, acts or inaction of Congress that, outside the control of DOE or Purchaser, affect DOE's ability to accept or the Purchaser's ability to deliver, SNF in a timely manner), fires, floods, epidemics… the parties will readjust their schedules, as appropriate, to accommodate such delay."

5. Policies for Decisionmakers to Pursue

There are several nuclear waste policy topics that U.S. decisionmakers could consider taking action on in particular:

A. Dedicated Escrow or Trust Accounts Instead of Payments to the Nuclear Waste Fund

As noted earlier, the BRC recommended that DOE offer to enter into negotiations with contract holders to revise the current contracts and provide new payment options in which payments to the NWF would be based on actual appropriations from the NWF and the remainder of the fee would be placed into a third-party escrow account. While this has not happened yet for the existing fleet, a similar approach for advanced reactor deployment could be useful to consider.

An outstanding question related to new advanced reactor deployment relates to paying for the ultimate disposition of the SNF that they will produce. In 2014, the U.S. courts shut off the fees that nuclear power plant owners were paying into the NWF, which would imply that, at least nominally any new advanced reactors would not be setting aside any money for future SNF disposition – an undesirable outcome.

One model for restructuring the standard contract to address this issue could come from the funds that nuclear power plant owners are required to set aside for decommissioning activities after a plant is shut down at the end of its lifetime. The NRC established financial requirements in 1988 to assure that adequate licensee funds would be available for decommissioning of all licensed facilities.[31] The NRC defines "decommission" in 10 CFR Part 50.2 to be "remove a facility or site safely from service and reduce residual radioactivity to a level that permits: (1) release of the property for unrestricted use and termination of the license; or (2) release of the property under restricted conditions and termination of the license." That is, the decommissioning described in NRC regulations is exclusively related to radiological decommissioning.

10 CFR Part 50.75 establishes requirements for how licensees will indicate to the NRC how they will provide "reasonable assurance" that funds will be available for the decommissioning process. The section of 50.75 identifies several avenues by which financial assurance can be provided, including setting aside money in a trust, escrow account, or Government fund. According to the Nuclear Energy Institute, the most common method of meeting these requirements is with a trust (typically called a Nuclear Decommissioning Trust).[32]

10 CFR Part 50.82 governs the use of decommissioning funds. No disbursement from the trust, escrow account, Government fund, or other account can be made, except under 50.82 or only after notifying the NRC of the intended usage and the NRC not objecting.

A similar approach could be considered for advanced reactor deployment to ensure funds will be available for SNF disposition. That is, a new requirement could be added to a revised standard contract between the federal government and advanced reactor owners that requires money to be set aside in a dedicated trust or escrow account (to be clear, this would not be a federal account) that cannot be used for other purposes. The revised standard contract could also allow for the possibility that the NWF gets used in the future for repository development, and perhaps require the advanced reactor owner to pay an amount to the NWF that matches actual appropriations in the same or previous year, as suggested by the BRC.[33] The possible arrangement is depicted in Figure 1.

Figure 1 Block diagram of payments from reactor owners into dedicated escrow or trust account to pay for SNF disposition activities at a later time.

This approach may also allow for a revised formula that better connects payments for disposal with SNF. The original NWPA set the rate at 0.1 cents per kWh generated from nuclear power plants, which tied payment to the amount of electricity produced, not the physical characteristics of the SNF that relate to disposal. The NWPA did allow the Secretary of Energy to adjust this fee, though right up until the day the courts shut off the fee, it remained at 0.1 cents per kWh generated.

Arguably, given that advanced reactor SNF has characteristics that are materially different from the LWR SNF that the current fleet produces, they should be treated differently than LWRs in terms of this nominal 0.1 cents per kWh generated to account for SNF disposition. For example, as discussed earlier, reactors that operate at higher temperatures than LWRs (e.g., greater than 600 degrees Celsius as compared to 300 degrees Celsius) should be able to achieve higher efficiencies in converting their heat to electricity, which in turn means less fission products generated per MWh. Hence, it would be reasonable to argue that these reactors should get credit in their fee payments for this reduction in waste per MWh generated (as quoted earlier, the BRC estimated a 25% reduction in repository space requirements as compared with LWRs operating on a once-through fuel cycle). [34]

Similarly, fast reactors operating on a closed fuel cycle would have some waste management advantages over a light water reactor system in that, in addition to operating at high temperature and higher conversion efficiencies, they would also produce few actinides on a per MWh basis on account of the reprocessing and subsequent transmutations. From earlier, the BRC estimated that a fast reactor system operating on a closed fuel cycle might reduce repository space by 75% compared with a LWR system normalized to the amount of electricity generated. If the government intends to take title of the SNF and HLW remaining after these separations and transmutations, it would be reasonable to consider a lower fee payment. On the other hand, recycling SNF creates additional waste streams, which results in a more complex waste management system than a once-through system, and this will also have to be taken into consideration.[35] Both a 2008 National Academies report, as well as the 2012 BRC report, judged that it would be premature for the United States to commit to closing the nuclear fuel cycle, but assessed that R&D into advanced fuel cycles would be valuable.[36]

It is possible that a successful trust fund or escrow approach crafted for advanced reactor deployment might indirectly help with an ongoing challenge related to the existing fleet of reactors. As mentioned, the NWF fee payment collection by DOE was stopped in 2014 after a court decision in 2013. At the time, utilities had been paying about $750 million a year in fees. Thus, if the courts had not shut off the fees, about $6.75 billion (though somewhat less, given several reactor retirements) would have been paid into the NWF in the intervening years, to pay for the disposal of the associated SNF. Moreover, if that money had been paid into the fund it would have been accruing interest, leading to an even greater balance. In general, each year that the utilities are not setting aside money for the disposal of the roughly 2,000 metric tons of SNF produced by the existing fleet, the gap between the funds available and what may be needed in the future will continue to grow.

As the gap in money owed to the NWF grows, it could become more challenging to access these funds at a later time. In the extreme, the possibility of a utility going bankrupt cannot be fully ruled out, in which case the financial obligations associated with the SNF disposition may fall on federal and/or state taxpayers. Even if the fee were restarted in 2024, if it were done in a manner that only charged fees going forward (and thus not charging the fee for previous years going back to when the federal courts shut them off) it would be giving a free ride to the reactors that had shut down in the last decade with respect to paying for the cost of disposal for the spent fuel discharged between 2014 and the time each reactor ceased operations.

In contrast to the case with advanced reactors, where no standard contract has been written and a new one could be drafted by the federal government, the owners of the existing fleet already have contracts in place. These contracts, and the federal government’s failure to live up to its end of the contract, are the basis for the lawsuits filed against the federal government in recent decades that have cost the federal taxpayer billions of dollars out of the unappropriated Judgment Fund. The contracts cannot be re-negotiated without consent by both parties, which could be difficult amidst the ongoing litigation. Still, charting a new course, by setting aside funds for SNF from advanced reactor deployment in a dedicated escrow or trust fund might present a model for the existing fleet to utilize in the future.

B. A Dedicated Office at DOE

The BRC recommended the creation of a new, single purpose organization dedicated solely to implementing the waste management program and "empowered with the authority and resources to succeed." While legislation has been introduced and discussed in hearings that would create a new organization, none of these bills have passed into law. A small, but perhaps more achievable, step in that direction, however, could be to establish a dedicated office inside DOE for waste management, reporting to the Secretary of Energy.

The NWPA created the office of Civilian Radioactive Waste Management (OCRWM) to carry out the implementation of the Act. The Obama Administration closed OCRWM in 2010 and transferred its functions to the Office of Nuclear Energy where it remains today. Thus, for over a decade, the federal SNF and HLW management function has been not just within an agency that has many missions and competing priorities (nuclear weapons, cleaning up of nuclear weapons sites, naval reactors, science, renewable energy, fossil energy, etc.) but within an Assistant Secretary-level office with other competing priorities (reactor research and development, university funding, international programs).

Establishing a dedicated office at DOE that reports to the Secretary of Energy would be an improvement over the current organizational structure by removing competing priorities (e.g., other programs in the Office of Nuclear Energy) as well as layers of bureaucracy (i.e., the Undersecretary of Energy). The idea appears to have broad support. For instance, a 2021 letter from eight different organizations to Secretary of Energy Granholm requested that she establish a dedicated office for implementing U.S. nuclear waste management.[f] The letter cited reasons to do so including providing a focal point for work on SNF and HLW, facilitating engagement with external stakeholders, and demonstrating an intent to take meaningful action.

Policymakers could also focus on measures that would help with continuity between Administrations for this dedicated office. For example, HR.3053 in the 115th Congress, which passed the House of Representatives, but never received a vote in the Senate, would have

[f] The letter to Secretary of Energy Granholm can be found at: https://thenwsc.org/wp-content/uploads/2021/05/Joint-Ltr-to-DOE-Secretary-Granholm-re-Dedicated-NW-Mgmt-Office-050321.pdf

reestablished OCRWM that had been closed in the Obama Administration. HR.3053 would have further established a five-year, fixed-term appointment for the OCRWM Director. The committee report for HR.3053[37] assessed that in doing so, the waste management program would gain continuity through presidential administrations and "elevate the position to inspire confidence in potential candidates…" The bill also would have allowed the Director of OCRWM, upon expiration of their first term, to continue serving for a year more, unless a new Director was confirmed. It also stated that the president could only remove the Director for inefficiency, neglect of duty, or malfeasance in office, and if the President removed the Director, the President would be required to submit a report to Congress explaining the reasoning behind it. The committee report noted that these provisions were intended to avoid the "repeated vacancies that plagued the program" during OCRWM's history, as Acting Directors did not have the full credibility and authority of a Senate-confirmed Director.

C. Regional Approaches to Consolidated Interim Storage

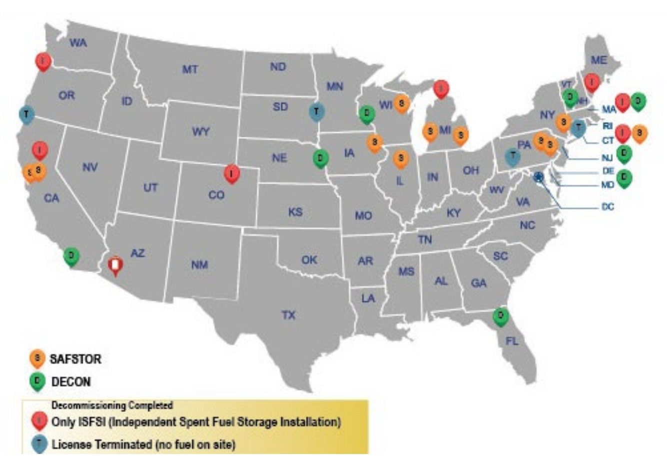
The Blue Ribbon Commission recommended development of one (or more) consolidated interim storage facilities. Eight years later, Congress appropriated $20 million dollars in FY2021 expressly for a "consent-based siting" effort to support the establishment of a consolidated interim storage facility.

In the interim, private entities had already been developing consolidated interim storage projects in both New Mexico and Texas. However, Governors and members of Congress from those states have firmly announced their opposition to the projects, in part citing a lack of any movement from the federal government on disposal plans, which could lead to interim sites being de facto long-term sites.[38][39] Moreover, in August of 2023, the U.S. Court of Appeals for the 5th Circuit rule that the NRC did not have the authority to issue licenses for private parties to store SNF at sites other than reactor locations.[40]

A different approach to consolidating SNF inventories that might plausibly encounter less public opposition could be to consider regional or even intrastate approaches. Individual states or select regions might see different advantages to the consolidation of SNF, especially from shutdown plant sites. While less efficient and more costly than a single consolidated interim site, this approach would reduce the number of interstate shipments and involve a smaller number of cask-miles for a given transportation campaign. Moreover, if a given state was not accepting SNF from shutdown sites over the entire United States, or even less than half of the shutdown sites, this might be more acceptable to state officials. Inside a single state, consolidation of sites might be even more palatable because the state isn't accepting SNF from any other state and at the end of the process, the hosting state would at least have a smaller number of storage sites inside its borders than it began with (with local communities able to fully reclaim the land associated with the other sites).

Figure 1 show the spread of shutdown power reactors around the United States and their decommissioning status. Table 1 lists the states, grouped by NRC region, with shutdown reactors and the number of these reactors in each region. (The four NRC regions are an already-defined grouping structure to help illustrate the regional concept, though it is not being suggested here that this should necessarily be the U.S. approach.)

Figure 1 shows the spread of shutdown power reactors around the United States and their decommissioning status. Table 1 lists the states, grouped by NRC region, with shutdown reactors and the number of these reactors in each region. (The four NRC regions are an already-defined grouping structure to help illustrate the regional concept, though it is not being suggested here that this should necessarily be the U.S. approach.)



Source: Nuclear Regulatory Commission, 2022
Note: The sites where no fuel remains on site are not included in Table 1.

As mentioned, regional or intrastate consolidated interim storage facilities are not likely to achieve as great a cost savings to the U.S. taxpayer as one national facility would – theoretically – in terms of lower overall transportation costs and security and operational costs after the transportation campaign is finished. However, if such an approach proved to be more politically palatable than an approach premised on only one consolidated interim storage facility, it may be preferable than continuing to push theoretically lower cost approaches that are not able to make progress in reality.

Even if regional or intrastate storage were more palatable to states or a single state, there are provisions in the NWPA that would have to be changed to permit this arrangement if the storage site was to be managed by DOE. The NWPA does not allow DOE to construct a consolidated interim storage facility until the first deep geologic repository developed under the Act has been issued a construction license by the NRC – and this development does not appear to be imminent. However, Congress might be inclined to permit such an arrangement on a case-by-case basis if a state or region asked for this change in law to better manage their SNF, especially from shutdown plants.

Table 2 Shutdown reactors by state and NRC region[41]

State	Shutdown Reactors
NRC Region I	
Connecticut	2
Maine	1
Maryland	1
Massachusetts	2
New Jersey	1
New York	3
Pennsylvania	3
Vermont	1
NRC Region II	
Florida	1
NRC Region III	
Illinois	3
Michigan	3
Wisconsin	2

NRC Region IV	
California	6
Colorado	1
Nebraska	1
Oregon	1

Source: Nuclear Regulatory Commission, 2022

D. Establishing a Greater-Than-Class-C Nuclear Waste Disposal Capability

The BRC noted that DOE has statutory responsibility for disposing of another nuclear waste inventory (in addition to SNF and HLW) whose disposal pathway remains unresolved: GTCC nuclear waste. GTCC waste is produced at LWRs (described below) and some of amount of it is likely to be produced by advanced reactors, too (as discussed, fusion power plants may also produce GTCC waste).[42] The GTCC inventory is small in volume compared with the Class A, B, and C low-level waste that is produced at commercial nuclear power plants, and is small in terms of total radioactivity when compared to the commercial SNF inventory, but it must still be removed from shutdown nuclear power plants in order to fully clean up the site. Unlike commercial SNF there is no potential energy value to GTCC nuclear waste – it is clearly a waste in need of a disposal pathway. In 2012, consistent with other assessments, the BRC report stated that GTCC wastes were "not generally acceptable for near-surface disposal."

However, this broad assessment has changed in the intervening years. In 2019, the NRC issued a draft regulatory basis for disposal of GTCC and transuranic waste, which found that most of the U.S. GTCC inventory was potentially suitable for near-surface disposal.[43] This section presents some background on GTCC waste, a short history of federal efforts to establish a GTCC disposal capability, and policy actions for decision-makers to consider.

Background

The United States maintains four operating disposal sites that are capable of disposing of Class A, B, and C low-level nuclear waste (LLW), in order of increasing radionuclide concentration. The limits for Class C nuclear waste – from 10 CFR Part 61.55 – are shown in Table 1. 10 CFR Part 61.55 also has a second table with limits for other radionuclides, as well, including Nickel-63 (in activated metal or not), Strontium-90, and Cesium-137. A material or component that exceeds the Class C limits for any one radionuclide – or for a combination of them using a sum of fractions rule defined in the regulation[g] – thus falls into the category of GTCC.

Table 3 Class C nuclear waste limits[44]

Radionuclide	Concentration curies per cubic meter
Carbon-14	8
Carbon-14 in activated metal	80
Nickel-59 in activated metal	220
Niobium-94 in activated metal	0.2
Technetium-99	3
Iodine-129	0.08
Alpha emitting transuranic nuclides with half-life greater than 5 years	100 (in nanocuries per gram)
Plutonium-241	3,500 (in nanocuries per gram)
Curium-242	20,000 (in nanocuries per gram)

Source: Nuclear Regulatory Commission, 2021

Over the course of a reactor's lifetime, the metal structures surrounding the fuel core become activated from neutrons produced in the fission reactions. At the time of decommissioning, it is possible that the levels of activation in these metals exceed the Class C limits. For sites with reactors that have reached the end of their operating lifetimes, after the power plant has otherwise been decommissioned, all that may be left at the site are casks with SNF and GTCC waste – neither of which have a disposal site or interim storage site that they can be transported to.[45]

Similar to the existing fleet of LWRs, some advanced reactors may produce GTCC waste by the end of their lifetimes (or during operation). Even fusion reactors, while they do not produce SNF, may produce some amount of GTCC given the large numbers of neutrons produced in fusion reactions such as deuterium-tritium fusion.[46] In that sense, the United States making progress on GTCC disposal might even be helpful to companies trying to commercialize fusion concepts.

[g] 10 CFR Part 61.55 (a)(7) defines the sum of fractions rule for mixtures of radionuclides.

Of course, commercial nuclear power is not the only source of GTCC nuclear waste. Medical procedures commonly utilize "sealed sources" that contain radioactive materials such as Cesium-137, and the radionuclide concentrations in these sealed sources can and do exceed Class C nuclear waste limits. Radioactive waste that is owned or generated by DOE and has characteristics similar to those of GTCC nuclear waste is termed "GTCC-like waste" by DOE, and includes, for example, streams from the West Valley Demonstration Project.

In its 2019 draft regulatory basis for disposal of GTCC and transuranic waste, the NRC identified 17 different GTCC waste streams that included GTCC waste from both existing facilities and activities and *potential* facilities and activities (e.g., Molybdenum-99 productions facilities that were in development).[47] As shown in Table 2, NRC staff assessed that a majority of GTCC from existing facilities and activities was potentially suitable for near-surface disposal (i.e., in or within the upper 30 meters of the Earth's surface), with the exception of two waste streams: sealed sources associated with neutron irradiators and remote-handled other waste from decontamination activities at the West Valley Demonstration Project. According to the NRC assessment, these would need to be disposed of in a deep geologic repository.

Table 4 Suitability of GTCC waste from existing facilities and activities for near surface disposal [48]

Existing facilities and activities	Waste containers CH or RH	GTCC volume (meters cubed)	Potentially suitable for near-surface disposal
Commercial reactors (activated metals)	RH	880	Yes
Sealed sources (Cesium-137)	CH	1,000	Yes
Sealed sources (neutron irradiators)	CH	1,800	No
West Valley Decontamination of Main Plaint Process Building (GTCC-like other waste)	CH	710	Yes
	RH	540	No

Source: Nuclear Regulatory Commission, 2019
Note: CH=contact handled, RH= remote handled

While Table 2 only shows GTCC inventories for existing facilities and activities, NRC analyzed 10 other potential facilities and activities that might produce more GTCC (by volume) in the future including exhumation of the West Valley site, Plutonium-238 production, and Molybdenum-99 production facilities.

In its draft regulatory basis, the NRC considered stronger measures that would potentially apply to GTCC disposal, as compared to, say, Class C nuclear waste disposal. For example, the NRC requires Class C waste to be disposed of either more than 5 meters below the surface of the Earth or to have a 500-year intruder barrier. For GTCC, NRC staff appear to be considering a requirement that a given disposal facility meet both of these conditions.

A Short History of Federal Efforts to Develop a GTCC Disposal Capability

When the NRC had first published regulations for land disposal of low-level radioactive waste (10 CFR Part 61) in 1982, the regulations stated that waste exceeding Class C limits was not generally acceptable for near-surface disposal and the waste form and disposal methods must be different, and in general more stringent, than those for Class C waste.[49] The 1982 rule did provide that proposals for disposal of this waste could be submitted to the Commission for approval. Congress first made GTCC disposal a federal responsibility in 1985 with the Low-Level Radioactive Waste Policy Amendments Act of 1985.[50]

A 1989 revision to 10 CFR Part 61.55(a)(2)(iv) amended this same section to say "In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository as defined in Part 60 of this chapter unless proposals for disposal of such waste in a disposal site licensed pursuant to this part art approved by the Commission."[51] In the 1987 amendments to the Nuclear Waste Policy Act of 1982, Yucca Mountain was named as the only place in the United States where DOE could conduct site characterization activities for a potential deep geologic repository for HLW. In the years that followed, DOE did give some consideration to disposing of GTCC waste in that potential facility.[h] However, as described earlier, the Yucca Mountain project has not received appropriation to move it forward since 2010, and in more recent years, DOE has not considered Yucca Mountain as a specific disposal pathway for GTCC waste.

[h] The U.S. government had considered Yucca Mountain as a potential disposal option according to page 9 of GAO, "Commercial Nuclear Power: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned," April 2011. https://www.gao.gov/assets/gao-11-229.pdf

In 2016, DOE published a report, "Final Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste."[52] The FEIS identified the preferred alternative for disposal of GTCC and GTCC-like waste as generic commercial facilities (i.e., private, not government-owned) and/or the Waste Isolation Pilot Plan (WIPP) in New Mexico. The FEIS did not identify a preference between the land disposal technologies that could be potentially utilized at generical commercial facilities (intermediate depth boreholes, enhanced near-surface trenches, and above-grade vault facilities.)

In 2017, DOE published a report to Congress on "Alternatives for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste and Greater-Than-Class C-like Waste" which provided an overview of the disposal alternatives analyzed in the FEIS.[53] The report described legislation that would be required for DOE to implement its preferred disposal alternative, and also recommended an approach to funding GTCC disposal similar to that used by commercial sites for Class A, B, and C LLW disposal – a fee assessed to the generated at the time the waste is delivered for disposal.

Related to commercial facility development, Waste Control Specialists had submitted to the Texas Commission on Environmental Quality in 2014 a petition for rulemaking that would allow for disposal of GTCC, GTCC-like, and transuranic waste. In 2015, the Texas Commission on Environmental Quality had sent a letter to the NRC inquiring about the State's authority to license a disposal capability for GTCC, GTCC-like and transuranic waste.[i] This, in turn, led the NRC to prepare a regulatory basis for GTCC, which led to the aforementioned 2019 document.[j] While DOE published an Environmental Assessment of the Waste Control Specialists site in Andrews County, Texas in 2018, GTCC disposal in Texas remains illegal.[54]

Actions for Policymakers

From a technical point of view, a GTCC disposal capability would exist somewhere in between LLW – where the United States has an operating disposal capability – and HLW – where the United States does not. Some GTCC waste could be disposed of in "enhanced" near surface facilities that would be more robust compared with disposal requirements for Class C waste,

[i] The TCEQ letter can be found here: https://www.nrc.gov/docs/ML1503/ML15034A181.pdf
[j] The history of this exchange can be found on the NRC website at: https://www.nrc.gov/waste/llw-disposal/llw-pa/gtcc-transuranic-waste-disposal.html

though two GTCC waste streams were assessed by NRC to require disposal in a deep geologic repository environment. As with commercial SNF, GTCC disposal is a federal responsibility and a greater focus on GTCC from policymakers could help to build capacity within the U.S. nuclear waste management system, in turn potentially helping to build momentum towards establishing a HLW disposal capability.

Congress. As raised in Section VIII of the 2017 Report to Congress from DOE, there are several legislative actions from Congress that would be needed for DOE to implement the preferred alternative for GTCC and GTCC-like disposal. Apart from questions over how GTCC disposal will be paid for, legislative action would also be needed if WIPP were going to be part of the GTCC disposal solution, given its statutorily defined mission to dispose of TRU waste from defense activities. DOE also requested clarification regarding section 3(b)(2) of the Low-Level Radioactive Policy Amendments Act of 1985, which says that GTCC resulting from activities licensed by the NRC is to be disposed of in a facility licensed by the NRC. For example, the NRC does not license DOE facilities (such as WIPP). Likewise, NRC staff have raised the question of whether an Agreement State can license a facility for GTCC disposal.[k] NRC's position has been that an Agreement State can license such a facility, but to remove any questions on the matter, Congress could provide clarification on the matter.

NRC. The NRC initiated a new 10 CFR Part 61 rulemaking process in 2009 to specify requirements for site-specific analysis and other requirements for unique wastes streams, including the disposal of significant quantities of depleted uranium.[l] In 2020, NRC staff recommended that this Part 61 rulemaking be combined with the rulemaking effort related to GTCC, which the Commission agreed to. The Part 61 rulemaking has thus been a long process that is not complete, and one where GTCC disposal was added to the rulemaking deliberations years after they started for a different purpose. A May 2023 public meeting identified that the next steps were to deliver a proposed rule to the Commission, with a public comment period to follow, and afterwards a final rule – implying the process will take at least

[k] For example, there are differing views amongst NRC staff on whether the Low-Level Radioactive Waste Policy Amendments Act of 1985 and the Atomic Energy Act of 1954, as amended, would allow GTCC waste disposal to be regulated by Agreement States. https://www.nrc.gov/docs/ML2014/ML20143A166.pdf
[l] A full history of this Part 61 rulemaking can be found on the NRC website: https://www.nrc.gov/waste/llw-disposal/llw-pa/uw-streams.html (accessed August 13, 2023)

years longer to finish. [55] However, finishing the Part 61 rulemaking is still an important action for the Commission to emphasize and see through to the end.

DOE. Finally, responsibility for implementing the GTCC program belongs to DOE, and the Secretary of Energy could decide to make the issue a priority. DOE has yet to select a site (or multiple sites) for GTCC disposal and certainly, with respect to the commercial site option, it would make sense to wait for NRC to finish the Part 61 rulemaking. But negotiations between states and DOE officials, potentially including the Secretary of Energy, may be pivotal to the success of the effort. As mentioned earlier, there is ongoing opposition in the two states of New Mexico and Texas to the private consolidated interim storage projects under development in each state for commercial SNF. The resulting tensions are likely creating a more challenging environment that works against the possibility of negotiating new disposal capabilities.

Endnotes

[1] Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy," January 2012. https://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov/

[2] Walker, J. Samuel. The Road to Yucca Mountain: The Development of Radioactive Waste Policy in the United States, 2009.

[3] Hamilton, Chainnan, and Chainnan Scowcroft, "STATEMENT OF MICHAEL F. HERTZ DEPUTY ASSISTANT ATTORNEY GENERAL, CIVIL DIVISION U.S. DEPARTMENT OF JUSTICE BEFORE THE BLUE RIBBON COMMISSION ON AMERICA'S NUCLEAR FUTURE FEBRUARY 2, 2011," February 2, 2011. https://www.justice.gov/d9/testimonies/witnesses/attachments/02/02/11//02-02-11-civ-hertz-testimony-for-blue-ribbon-commission-on-americas-nuclear-future.pdf.

[4] Halstead, Robert J. Mushkatel, Alvin. Thomas, Kathy. "Remaking the US Nuclear Waste Program: A Window of Opportunity for Change?", Waste Management 2015 Conference, March 15-19, 2015, Phoenix, Arizona. https://anp.nv.gov/uploadedFiles/nucwastenvgov/content/HotTopics/Remaking%20the%20US%20Nuclear%20Waste%20ProgramADA.pdf.

[5] Public Broadcast Service, "Early Caucus Dates Bring Nevada into Focus for 2008 Election," November 12, 2008. https://www.pbs.org/newshour/show/early-caucus-dates-bring-nevada-into-focus-for-2008-election

[6] Sands, Derek, "US House science lawmakers spar over Yucca Mountain," S&P Global Commodity Insights, October 27, 2011. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/102711-us-house-science-lawmakers-spar-over-yucca-mountain

[7] *Nat'l Ass'n of Regulatory Util. Comm'rs v. U.S. Dep't of Energy*, No. 11-11066 (D.C. Circ. Nov. 19, 2013). https://www.cadc.uscourts.gov/internet/opinions.nsf/2708C01ECFE3109F85257C280053406E/$file/11-1066-1466796.pdf

[8] World Nuclear News, "Zero day for US nuclear waste fee," May 16, 2014. https://www.world-nuclear-news.org/Articles/Zero-day-for-US-nuclear-waste-fee.

[9] Wolff, Eric, Adragna, Anthony, "Trump's Nevada play leaves nation's nuclear waste in limbo," February 2, 2022. https://www.politico.com/news/2020/02/22/trump-nevada-nuclear-waste-yucca-mountain-116663

[10] Department of Energy, "The Report to the President and the Congress by the Secretary of Energy on the Need for a Second Repository," December 2008. https://www.energy.gov/articles/report-president-and-congress-secretary-energy-need-second-repository

[11] Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy," January 2012. p. vii- xv. https://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov/

[12] Department of Energy, "DOE Awards $26 Million to Support Consent-Based Siting for Spent Nuclear Fuel," June 9, 2023. https://www.energy.gov/articles/doe-awards-26-million-support-consent-based-siting-spent-nuclear-fuel

[13] Erica Bickford, "Atlas and Fortis Railcar Project Updates," Presentation to the Nuclear Waste Technical Review Board, March 28, 2023.

[14] Gerard Jackson, "Nuclear Power Plant Infrastructure for Removing Commercial Spent Nuclear Fuel," Presentation to the Nuclear Waste Technical Review Board, March 28, 2023.

[15] Patrick Schwab et al., "Update on Development of a U.S. Rail Transport Capability for Spent Nuclear Fuel and High-Level Waste" Waste Management 2020 Conference. Phoenix, AZ. March 8–12, 2020.

[16] Nuclear Energy Institute, "Cost Competitiveness of Micro-Reactors for Remote Markets," April 15, 2019. https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/Report-Cost-Competitiveness-of-Micro-Reactors-for-Remote-Markets.pdf

[17] National Academies of Sciences, Engineering, and Medicine. 2023. *Laying the Foundation for New and Advanced Nuclear Reactors in the United States*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26630

[18] National Academies of Sciences, Engineering, and Medicine. 2023. 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. (NAS 2023) https://doi.org/10.17226/26500

[19] Paul Day, "U.S. ramps up advanced fuel production capabilities," Reuters, February 16, 2023. https://www.reuters.com/business/energy/us-ramps-up-advanced-fuel-production-capabilities-2023-02-16/

[20] Oklo. "Oklo Inc. - Investor Relations." Accessed September 19, 2023. https://www.oklo.com/.

[21] National Academies of Sciences, Engineering, and Medicine. 2023. *Laying the Foundation for New and Advanced Nuclear Reactors in the United States*. Washington, DC: The National Academies Press. p. 163-166. https://doi.org/10.17226/26630

[22] Idaho National Laboratory, "Idaho National Laboratory Preferred Disposition Plan for Sodium-Bonded Spent Nuclear Fuel," January 2007. https://s3.amazonaws.com/ucs-documents/nuclear-power/Pyroprocessing/INL+Preferred+Disposition+Plan+for+Sodium-Bonded+Spent+Nuclear+Fuel.pdf

[23] U.S. Nuclear Waste Technical Review Board, "Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel," December 2017. https://www.nwtrb.gov/docs/default-source/reports/nwtrb-mngmntanddisposal-dec2017-508a.pdf?sfvrsn=14

[24] E.g., see X-energy's webpage on their HTGR's fuel: https://x-energy.com/fuel/triso-x

[25] National Academies of Sciences, Engineering, and Medicine. 2023. *Laying the Foundation for New and Advanced Nuclear Reactors in the United States*. Washington, DC: The National Academies Press. p. 159-163. https://doi.org/10.17226/26630

[26] National Academies of Sciences, Engineering, and Medicine. 2023. *Laying the Foundation for New and Advanced Nuclear Reactors in the United States*. Washington, DC: The National Academies Press. p. 12, 66-67, 166-168. https://doi.org/10.17226/26630

[27] Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy," January 2012. p. 102- 106. https://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov/

[28] NuScale, "Neutron Bytes: Interview with NuScale's Jose Reyes," June 4, 2019. https://www.nuscalepower.com/en/news/press-releases/2019/neutron-bytes-interview-with-jose-reyes

[29] National Academies of Sciences, Engineering, and Medicine. 2023. *Laying the Foundation for New and Advanced Nuclear Reactors in the United States*. Washington, DC: The National Academies Press. p. 169-177. https://doi.org/10.17226/26630.

[30] National Conference of State Legislatures, "States Restrictions on New Nuclear Power Facility Construction," August 17, 2021. https://www.ncsl.org/environment-and-natural-resources/states-restrictions-on-new-nuclear-power-facility-construction

[31] Volume 53 of the Federal Register, page 24018 (53 FR 24018); June 27, 1988.

[32] Nuclear Energy Institute, "Use of the Nuclear Decommissioning Trust Fund," NEI 15-06, Revision 0, November 2015. https://www.nrc.gov/docs/ML1533/ML15335A187.pdf

[33] Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy," January 2012. p. 117. https://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov/

[34] Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy," January 2012. p. 104. https://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov/

[35] Massachusetts Institute of Technology, "The Future of the Nuclear Fuel Cycle," 2011. p. 157-158. https://energy.mit.edu/wp-content/uploads/2011/04/MITEI-The-Future-of-the-Nuclear-Fuel-Cycle.pdf

[36] National Research Council, "Review of DOE's Nuclear Energy Research and Development Program." Washington, DC: The National Academies Press. 2008. https://doi.org/10.17226/11998.

[37] House Energy and Commerce Committee, "Nuclear Waste Policy Amendments Act of 2017," October 19, 2017. https://www.congress.gov/115/crpt/hrpt355/CRPT-115hrpt355.pdf.

[38] Heinrich, Martin, Ben Ray Lujan, Melanie A Stansbury, and Michelle Lujan Grisham. "Letter to Sec. Granholm-Nuclear Waste and Holtec," July 1, 2021. https://www.heinrich.senate.gov/imo/media/doc/Letter%20to%20Sec.%20Granholm-Nuclear%20Waste%20and%20Holtec.pdf.

[39] Abbott, Greg. "Interim Storage Partners (ISP) Consolidated Interim Storage Facility Project, Docket ID NRC-2016-0231," November 3, 2020. https://gov.texas.gov/uploads/files/press/O-NuclearRegulatoryCommission202011030767.pdf.

[40] Pearl, Larry "NRC lacks authority to license private, away-from-reactor nuclear waste facility: 5th Circuit," Utility Dive, August 29, 2023. https://www.utilitydive.com/news/nrc-license-nuclear-reactor-spent-fuel-waste-storage-facility/692103/

[41] https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/decommissioning.html

[42] National Academies of Sciences, Engineering, and Medicine, *Bringing Fusion to the U.S. Grid.* Washington, D.C.: National Academies Press, 2021. p.40,45. https://doi.org/10.17226/25991.

[43] Nuclear Regulatory Commission, "Disposal of Greater-than-Class C (GTCC) and Transuranic Waste," Draft Regulatory Basis – For Public Comment, 2019. https://www.nrc.gov/docs/ML1905/ML19059A403.pdf

[44] Nuclear Regulatory Commission. "§ 61.55 Waste Classification.," March 24, 2021. Table 1. https://www.nrc.gov/reading-rm/doc-collections/cfr/part061/part061-0055.html.

[45] Department of Energy, "Nuclear Power Plant Infrastructure Evaluations for Removal of Spent Nuclear Fuel," April 30, 2021. https://www.energy.gov/ne/articles/nuclear-power-plant-infrastructure-evaluations-removal-spent-nuclear-fuel

[46] National Academies of Sciences, Engineering, and Medicine, *Bringing Fusion to the U.S. Grid.* Washington, D.C.: National Academies Press, 2021. p.45. https://doi.org/10.17226/25991.

[47] Nuclear Regulatory Commission, "Disposal of Greater-than-Class C (GTCC) and Transuranic Waste," Draft Regulatory Basis – For Public Comment, 2019. p. B-5. https://www.nrc.gov/docs/ML1905/ML19059A403.pdf

[48] Nuclear Regulatory Commission, "Disposal of Greater-than-Class C (GTCC) and Transuranic Waste," Draft Regulatory Basis – For Public Comment, 2019. p. 25. https://www.nrc.gov/docs/ML1905/ML19059A403.pdf

[49] "Alternative requirements for design and operations," *Federal Register* 47, No. 248. (December 27, 1982): 57473. https://archives.federalregister.gov/issue_slice/1982/12/27/57444-57482.pdf.

[50] Rep. Udall, Morris K. [D-AZ-2. H.R.1083 - 99th Congress (1985-1986): Low-Level Radioactive Waste Policy Amendments Act of 1985 (1986). https://www.congress.gov/bill/99th-congress/house-bill/1083.

[51] "Disposal of Radioactive Waste," *Federal Register* 54, No. 100. (May 25, 1989): 22578. https://archives.federalregister.gov/issue_slice/1989/5/25/22578-22584.pdf

[52] Department of Energy, "EIS-0375: Final Environmental Impact Statements," February 25, 2016. https://www.energy.gov/nepa/articles/eis-0375-final-environmental-impact-statement

[53] Department of Energy, "Alternatives for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste and Greater-Than-Class C-like Waste," November 2017. https://www.energy.gov/em/articles/2017-report-congress-disposal-alternatives.

[54] Department of Energy, "Environmental Assessment for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste at Waste Control Specialists, Andrews County, Texas," October 2018. https://www.energy.gov/sites/default/files/2018/11/f57/final-ea-2082-disposal-of-gtcc-llw-2018-10.pdf

[55] Nuclear Regulatory Commission, "Public Meeting: Regulatory Concepts for Integrated Low Level Radioactive Waste Disposal Rulemaking," May 17, 2023. Accessed August 13, 2023. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML23130A189