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Report to Congressional Addressees

September 2021

COMMERCIAL SPENT NUCLEAR FUEL

Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution

GAO-21-603

GAO@100

Highlights

Highlights of GAO-21-603, a report to congressional addressees

September 2021

COMMERCIAL SPENT NUCLEAR FUEL

Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution

Why GAO Did This Study

Commercial spent nuclear fuel is extremely dangerous if not managed properly. About 86,000 metric tons of this fuel is stored on-site at 75 operating or shutdown nuclear power plants in 33 states, an amount that grows by about 2,000 metric tons each year.

The NWPA, as amended, requires DOE to dispose of spent nuclear fuel and specifies that the only site that may be considered for the permanent disposal of commercial spent nuclear fuel is a geologic repository at Yucca Mountain, Nevada. However, in 2010, DOE terminated its efforts to license a repository at Yucca Mountain, and Congress stopped funding activities related to the site. Since then, policymakers have been at an impasse on how to meet the federal disposal obligation, with significant financial consequences for taxpayers.

This report examines actions that experts identified as necessary to develop a solution for spent nuclear fuel disposal. GAO reviewed DOE and other agency documents and interviewed 20 experts and 25 stakeholders from industry, nongovernmental organizations, and tribal and state groups.

What GAO Recommends

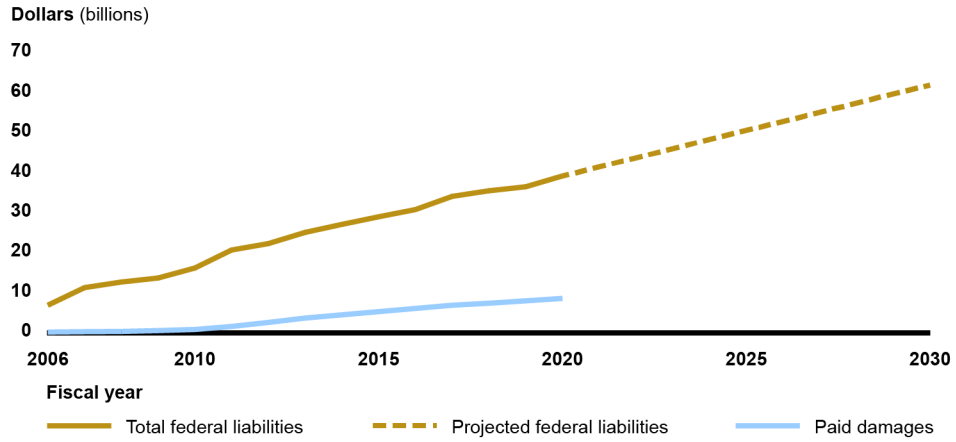
GAO is making four matters for congressional consideration, including (1) amending the NWPA to authorize a new consent-based siting process; (2) restructuring the Nuclear Waste Fund; and (3) directing DOE to develop and implement an integrated waste management strategy. GAO is also recommending that DOE finalize its consent-based siting process. DOE agreed with GAO's recommendation.

View GAO-21-603. For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

What GAO Found

Congress needs to take action to break the impasse over a permanent solution for commercial spent nuclear fuel—used fuel removed from nuclear power reactors—according to experts GAO interviewed. Specifically, most experts said Congress should (1) amend the Nuclear Waste Policy Act of 1982 (NWPA) to authorize the Department of Energy (DOE) to implement a new consent-based process for siting consolidated interim storage and permanent geologic repository facilities, and (2) restructure the Nuclear Waste Fund to ensure reliable and sufficient funding. Experts highlighted concerns about the effect of the continuing impasse on environmental, health, and security risks; efforts to combat climate change; and taxpayer costs. For example, the amount the federal government will have to pay to owners to store spent nuclear fuel at reactor sites will continue to grow annually (see figure).

Figure: Department of Energy Total Estimated Costs and Remaining Liabilities for Storing Commercial Spent Nuclear Fuel (SNF), in Billions of Dollars



Source: GAO analysis of Department of Energy financial reports. | GAO-21-603

Note: For more details, see figure 4 in GAO-21-603.

The United States currently has an ad hoc system for managing commercial spent nuclear fuel, which can affect future disposal decisions and costs. For example, spent fuel is stored using a variety of different technologies that will have implications for final disposal. Nearly all of the experts we interviewed said an integrated strategy is essential to developing a solution for commercial spent nuclear fuel and potentially reducing programmatic costs. However, DOE cannot fully develop and implement such a strategy without congressional action.

In 2015, DOE began efforts to engage the public and develop a draft consent-based siting process, but it has not finalized this process. The draft includes elements that nearly all experts agreed are critical for an effective siting process. Finalizing the draft could help position DOE to implement a consent-based process for consolidated interim storage facilities and/or permanent geologic repositories if Congress amends the NWPA to allow for storage and disposal options other than, or in addition to, the Yucca Mountain repository.

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Abbreviations

DOE	Department of Energy
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982

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Spent nuclear fuel—fuel removed from commercial nuclear power reactors after it has been used to produce electricity—can pose serious environmental, public health, and security risks if not properly managed. As of the end of 2019, about 86,000 metric tons of commercial spent nuclear fuel was being stored on-site at 75 operating or shut-down nuclear power plants in 33 states.[1] This amount of spent fuel is growing by about 2,000 metric tons annually.

The Nuclear Waste Policy Act of 1982 (NWPA), enacted in 1983, made the management and permanent disposal of commercial spent nuclear fuel a federal responsibility.[2] The NWPA directed the Secretary of Energy to investigate potential locations for permanent geologic repositories. It also established the Nuclear Waste Fund, which consists of fees from owners of commercial nuclear power reactors, to pay for, among other things, the development of such repositories. In 1987, Congress amended the NWPA to direct the Department of Energy (DOE) to focus its efforts solely on a permanent geologic repository at one site: Yucca Mountain, about 100 miles northwest of Las Vegas, Nevada.[3] The state of Nevada, many of its members of Congress, and several Native American tribes with ties to the lands surrounding Yucca Mountain have strongly opposed Congress designating Yucca Mountain as the sole site for a geologic repository. The 1987 amendments also precluded DOE from taking steps to develop a monitored retrievable storage facility—

[1]In addition to commercial spent nuclear fuel, the United States has about 14,000 metric tons of high-level waste and spent nuclear fuel from defense-related activities. From 1944 until the 1980s, the United States used nuclear reactors to produce plutonium and other materials to develop nuclear weapons. This waste is currently stored in facilities in five states and managed by the Department of Energy. We excluded defense high-level waste from this report, but the federal government is also responsible for permanently disposing of this waste. Examples of our recent work on defense high-level waste include GAO, *Nuclear Waste Disposal: Better Planning Needed to Avoid Potential Disruptions at Waste Isolation Pilot Plant,* GAO-21-48 (Washington, D.C.: Nov. 19, 2020) and *Nuclear Waste: Benefits and Costs Should be Better Understood Before DOE Commits to a Separate Repository for Defense Waste,* GAO-17-174 (Washington, D.C.: Jan. 31, 2017).

[2]Pub. L. No. 97-425, §§ 111-113, 96 Stat. 2201, 2207-12 (1983) (codified as amended at 42 U.S.C. §§ 10131-33).

[3]Pub. L. No. 100-203, tit. V, subtit. A, 101 Stat. 1330-227.

commonly referred to as a consolidated interim storage facility—where commercial spent nuclear fuel from numerous reactor sites could be collected and temporarily stored at a centralized facility designed, constructed, and operated by DOE, until the Secretary recommended to the President the approval of a site for development of a permanent repository.[4] This effectively tied the development of such a facility to Yucca Mountain. The amendments also essentially made the U.S. commercial spent nuclear fuel management program dependent on the construction of a permanent repository at Yucca Mountain.

In 2008, DOE submitted a license application to the Nuclear Regulatory Commission (NRC) for developing and constructing a repository at the Yucca Mountain site.[5] However, in a change of policy, in 2009, the Secretary of Energy announced that DOE no longer considered the Yucca Mountain site a viable option for a permanent repository. In 2010, DOE terminated its efforts to license a repository at Yucca Mountain. Furthermore, Congress has not funded activities related to developing a repository at Yucca Mountain since fiscal year 2010, and has not authorized DOE to explore the possibility of developing a repository at other sites. As a result, under current law, Yucca Mountain is the only location authorized for a permanent repository for the disposal of commercial spent nuclear fuel.

The development of the Yucca Mountain site remains unresolved, with significant short-term as well as potential long-term financial consequences for the federal government. For example, because a repository had not been constructed at Yucca Mountain, DOE could not meet its January 1998 deadline to begin disposing of spent fuel from commercial nuclear power reactor operators, stipulated by the NWPA. As a result, as of September 2020, the federal government had paid the owners of commercial nuclear power reactors almost $9 billion in damages for the costs they incurred to store spent fuel at reactor sites, according to DOE's *Fiscal Year 2020 Agency Financial Report*. These

[4]Under the NWPA, a monitored retrievable storage facility is to be designed, constructed, and operated by DOE. However, NRC also licenses consolidated interim storage facilities, which can be designed, constructed, and operated by a private commercial entity. In this report, unless otherwise specified, we use the term "consolidated interim storage facility" to mean a DOE monitored retrievable storage facility, a commercial storage facility, or both.

[5]NRC is the federal agency that regulates the storage, transportation, and disposal of commercial spent nuclear fuel.

costs will continue to grow until the federal government develops and approves a consolidated interim storage facility or permanent disposal repository and takes custody of the fuel. Specifically, in its *Fiscal Year 2020 Agency Financial Report*, DOE estimated the remaining federal liability for interim storage costs would be about $30.6 billion.[6] Based on our prior work, this may be an underestimate.[7]

The U.S. government faces billions of dollars in federal financial liabilities for not fulfilling its responsibilities for managing this material, as well as the potential risks associated with not developing a permanent disposal repository for spent nuclear fuel. Our work, performed under the authority of the Comptroller General, was to conduct evaluations in light of the billions of dollars in federal financial liabilities the U.S. government faces for not fulfilling its responsibilities for managing this material, as well as the potential risks associated with not developing a permanent disposal repository for spent nuclear fuel. We examined what actions may be necessary to address the impasse and effectively manage commercial spent nuclear fuel. Specifically, this report highlights actions that experts identified as necessary to develop a solution for the management of commercial spent nuclear fuel.

To answer this objective, we reviewed documents and interviewed DOE and NRC officials regarding their roles related to managing commercial spent nuclear fuel. We also interviewed Department of Justice officials and reviewed documents related to lawsuits filed by utilities against DOE for not fulfilling its obligation to dispose of commercial spent nuclear fuel. We also reviewed documents summarizing the damages paid by the federal government to nuclear utilities.

To determine options for managing commercial spent nuclear fuel and identify experts to interview, we reviewed studies and reports identified from our prior work, preliminary background research, referrals from experts and stakeholders we contacted, and working groups that

[6]Department of Energy, *DOE's Fiscal Year 2020 Agency Financial Report, DOE/CF-0170* (Washington, D.C.: Nov. 16, 2020).

[7]DOE has previously extended the dates for when it expects to collect commercial spent nuclear fuel from reactors. Each extension adds to the federal government's liability because the federal government has to continue to pay the owners of commercial nuclear power reactors for the costs they incurred to store spent fuel at reactor sites. For more information on DOE's liability estimates, see GAO, *Spent Nuclear Fuel Management: Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability,* GAO-15-141 (Washington, D.C.: Oct. 9, 2014).

examined policies for managing the back-end of the nuclear fuel cycle and made strategy recommendations to the federal government. To supplement this research, we conducted a literature review of articles and reports related to managing commercial spent nuclear fuel. To conduct the literature review, we searched Elsevier's Scopus and ProQuest databases using relevant key words (e.g., spent nuclear fuel, management, disposal, and transportation). In total, we reviewed about 150 reports.

We identified relevant experts in the fields of spent nuclear fuel management and public engagement using four sources: the literature review, participation in working groups, recommendations from other experts we interviewed, and participation in prior GAO engagements. We then selected 20 of these experts to interview based on the number of sources in which they were identified, with higher priority being given to experts who were identified in more sources (see app. I for the list of experts). We conducted semi-structured interviews with these experts, using a pre-tested set of questions, and conducted a content analysis of their responses.[8] We also identified and interviewed 25 stakeholders, including tribal, state, and local officials; owners of commercial nuclear power plants; nuclear industry trade groups; environmental organizations; and officials responsible for commercial spent nuclear fuel management in countries furthest along with siting and developing a geologic repository (i.e., Canada, Finland, and Sweden).[9] We selected stakeholders to interview based on their knowledge of the history of and policies for managing commercial spent nuclear fuel and to ensure they represented a diverse range of pro- and anti-nuclear views from various organizations. We conducted semi-structured interviews with these stakeholders. The views of these experts and stakeholders cannot be generalized to all such experts and stakeholders.

To understand the existing inventory of commercial spent nuclear fuel and estimates of future inventories, we reviewed and analyzed data from Gutherman Technical Services, LLC,[10] DOE, and NRC. We also reviewed

[8]To characterize the experts' views throughout this report, we defined the modifiers "nearly all" to represent 17 to 19 experts, "most" to represent 11 to 16 experts, "many" to represent seven to 10 experts, and "several" to represent three to six experts.

[9]We distinguished experts from stakeholders based on their education, work experience, publications, and years of experience.

[10]Gutherman Technical Services, LLC is a consulting firm that provides information on spent nuclear fuel inventories for the Nuclear Energy Institute.

and analyzed DOE data on fees collected from nuclear utilities for the Nuclear Waste Fund, and the interest accrued on those fees.

To determine the federal government's financial liability and fiscal exposure for commercial spent nuclear fuel, we reviewed DOE's annual agency financial reports and analyzed the dollar amounts that DOE has paid the owners of commercial nuclear reactors in damages for storing spent nuclear fuel at their reactor sites. We also reviewed and analyzed DOE's estimates of its potential long-term financial liabilities associated with its obligations to pay the owners of commercial nuclear reactors for the costs of storing spent nuclear fuel at reactor sites.

For any data and estimates we report, we reviewed the methodology to ensure the data and estimates were sufficiently sound and conducted a data reliability assessment on all data sources. Specifically, we assessed the reliability of the spent nuclear fuel inventory and projection estimates by interviewing a representative from Gutherman Technical Services, LLC and reviewing its data collection protocols. We assessed the reliability of the Nuclear Waste Fund data by (1) reviewing existing information about the data and the system that produced them and (2) interviewing DOE officials knowledgeable about the data. We assessed the reliability of the data in DOE's agency financial reports by relying on the audit results of the independent public accounting firm that audits DOE's financial statements. The audits identified no material weaknesses, instances of noncompliance with laws and regulations, or instances in which DOE's financial management stewardship and systems did not comply with governmental financial requirements. Based on these steps, we determined the estimates and data to be sufficiently sound and reliable for our purposes. For additional details on our scope and methodology, see appendix II.

We conducted this performance audit from May 2020 to September 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

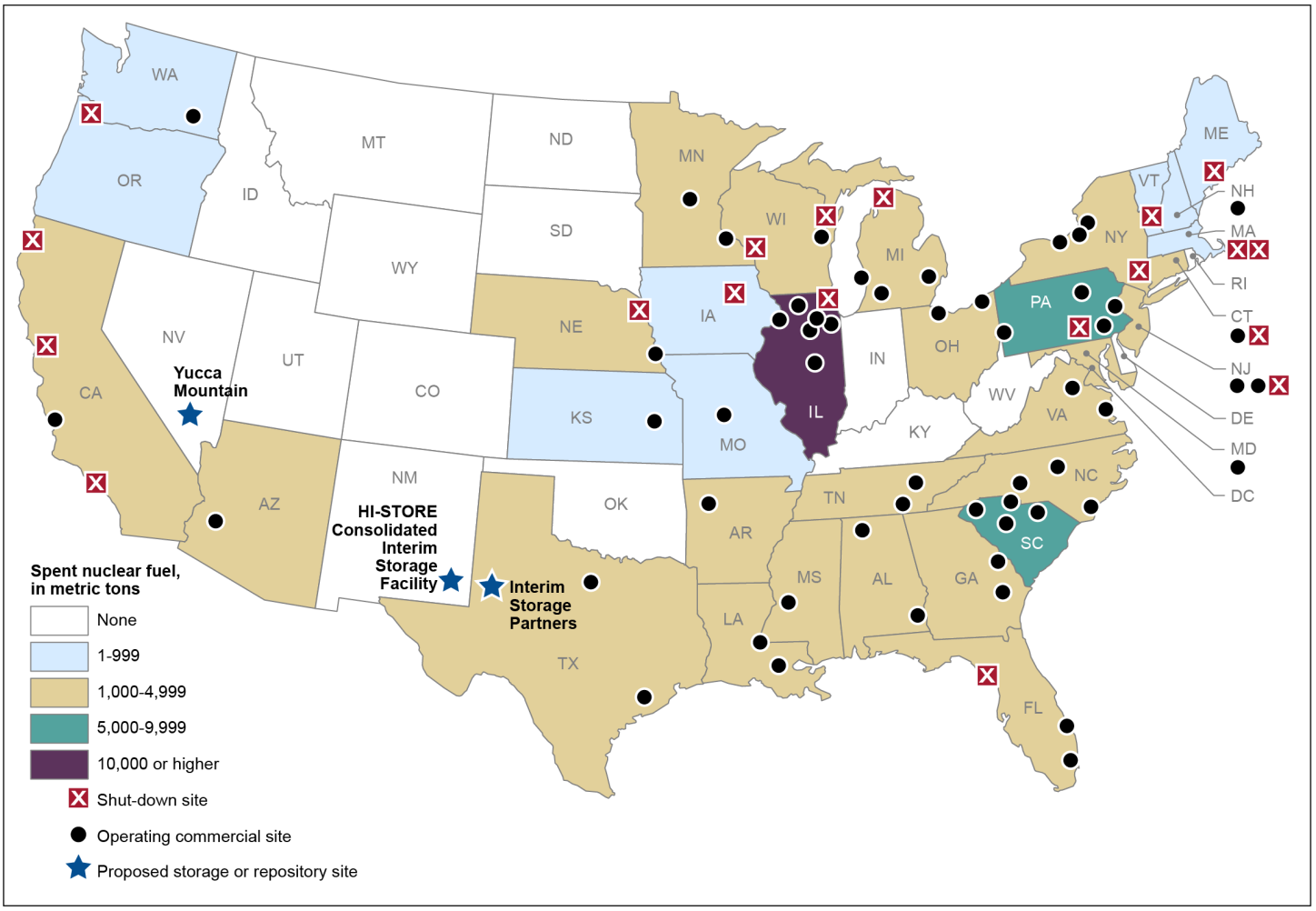
Commercial Spent Nuclear Fuel

The nation's spent nuclear fuel comes from several sources, including commercial nuclear power plants, the U.S. nuclear weapons program, and research reactors. This report focuses on spent nuclear fuel from commercial nuclear power plants. Fuel for commercial nuclear power reactors typically comes from low-enriched uranium fashioned into thumbnail-size ceramic pellets of uranium dioxide. These pellets go into 12- to 15-foot hollow fuel rods, bounded together into a larger fuel assembly. When operating, a typical reactor holds about 100 metric tons of fuel that are generally stored in roughly 200 to 800 fuel assemblies. The uranium in the assemblies undergoes fission—a process of splitting atoms into fragments and neutrons that then bombard other atoms—resulting in additional fission reactions and a sustainable chain reaction that creates an enormous amount of heat and radioactivity in the form of radioisotopes and other radioactive materials. The heat generated by this reaction heats water and produces steam that spins a turbine, which generates electricity. The radioisotopes produced in a reactor can remain hazardous from a few days to many thousands of years. These radioisotopes remain in the fuel assemblies and as components of what later becomes spent nuclear fuel.

After nuclear fuel is used, or "spent," and removed from reactors, operators must actively manage and monitor the material to safeguard human health and the environment and ensure that it is secure. As of the end of 2019, approximately 86,000 metric tons of spent nuclear fuel were stored on-site at 75 operating or shut-down commercial nuclear power plants in 33 states (see fig. 1). According to data provided by Gutherman Technical Services, LLC, an estimated 2,000 metric tons of commercial spent nuclear fuel is expected to accumulate annually over the next 10 years. Beyond the next 10 years, spent nuclear fuel is expected to accumulate at a slower rate as more reactors begin to shut down in the 2030s, resulting in an estimated total accumulation of 140,179 metric tons over the remaining lifetime of existing nuclear power plants.[11]

[11]The total amount of spent nuclear fuel that ultimately accumulates will depend on a number of factors, including how long existing nuclear power reactors continue to operate and how many new nuclear power reactors enter operation.

Figure 1: Stored Commercial Spent Nuclear Fuel Amounts, through 2019, and Locations, as of June 2021



Sources: GAO analysis of data from Gutherman Tehcnical Services, LLC, the Department of Energy, and the Nuclear Regulatory Commission; Map Resources (map). | GAO-21-603

Notes: Locations are approximate.

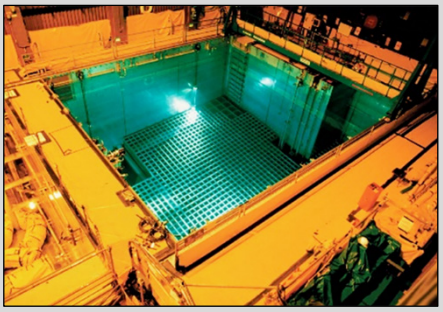
The Department of Energy (DOE) manages an inventory of formerly commercial spent nuclear fuel in Idaho and Colorado.

Several states have inventories of defense spent nuclear fuel.

The West Valley facility in New York reprocessed spent nuclear fuel from commercial and defense reactors in the 1960s and 1970s, but DOE and the state of New York disagree on who is responsible for paying to dispose of the spent fuel once a repository becomes available. New York state officials believe the spent nuclear fuel at West Valley is from federal defense activities, while DOE considers the waste commercial. For more information on the West Valley facility, see GAO, *Nuclear Waste: Congressional Action Needed to Clarify a Disposal Option at West Valley Site in New York*, GAO-21-115 (Washington, D.C.: Jan. 13, 2021).

Alaska and Hawaii are not pictured and have no commercial sites or commercial spent nuclear fuel inventory.

Cooling Pool Storage for Spent Nuclear Fuel



Fuel is typically used in a reactor for 4 to 6 years to generate electricity. After removal of spent fuel from a nuclear reactor, the fuel is stored in an immense pool of water designed to cool and provide shielding from radiation. Cooled water circulates in the pool to ensure the heat generated from decaying radioisotopes does not damage fuel assemblies and release radioactive material. Cooling pools for spent nuclear fuel are typically about 40 feet deep, with at least 20 feet of water covering the fuel. Industry practice has been to store spent nuclear fuel in cooling pools for at least 5 years or until the fuel has cooled enough to transfer to dry cask storage.

Source: Nuclear Regulatory Commission. | GAO-21-603

When commercial nuclear fuel is spent, or no longer efficient for generating electricity, it is initially stored immersed in pools of water designed to cool and isolate it from the environment. Water circulates in the pools to remove the heat generated from the radioactive decay of some of the radioisotopes. Industry practice has been to store the spent nuclear fuel in these pools for at least 5 years or until the fuel has cooled enough to transfer to dry cask storage. As we have previously reported, as reactor operators have run out of space in their spent fuel pools, more operators have turned to dry cask storage.[12] Dry cask storage consists of a steel canister that holds the fuel assemblies, protected by an outer cask made of steel or concrete and steel designed to cool the fuel and provide shielding from its radiation. A variety of canister designs exist for storing spent nuclear fuel, including canisters designed solely for on-site storage, as well as dual-purpose canisters—canisters designed for storage and transportation, but not for disposal of spent nuclear fuel in a repository.[13]

[12]GAO, *Commercial Spent Nuclear Fuel: Observations on the Key Attributes and Challenges of Storage and Disposal Options,* GAO-13-532T (Washington, D.C.: Apr. 11, 2013).

[13]Dual-purpose canisters containing commercial spent nuclear fuel will need to be loaded into containers designed for disposal prior to being placed in a geologic repository, according to a 2020 Sandia National Laboratories report. According to that report, DOE is investigating the technical feasibility of directly disposing of commercial spent nuclear fuel in dual-purpose canisters in a permanent repository because the quantity of spent fuel in dual-purpose canisters is much greater than that previously anticipated. For more information, see Sandia National Laboratories, *Analysis of Solutions for the Geologic Disposal of Dual-Purpose Canisters: Spent Fuel and Waste Disposition,* SAND2020-3756R (Albuquerque, NM: March 2020).

Dry Cask Storage Systems

Dry cask storage systems typically consist of a steel canister (holding fuel assemblies) protected by an outer cask made of steel or concrete and steel designed to cool the fuel and provide shielding from the fuel's radiation.

To transfer spent nuclear fuel from pools to dry cask storage, fuel assemblies are loaded into a steel canister with a lid while immersed in the pool. The canister is removed from the pool, the lid is welded onto the canister, the water is drained, and the canister undergoes a drying process. The steel canister goes into a larger storage cask made of steel or concrete and steel. Storage casks, in either vertical (as shown in the picture) or horizontal designs, are typically placed on a large concrete pad surrounded by safety and security measures, such as radiation detection devices and intrusion detection systems.

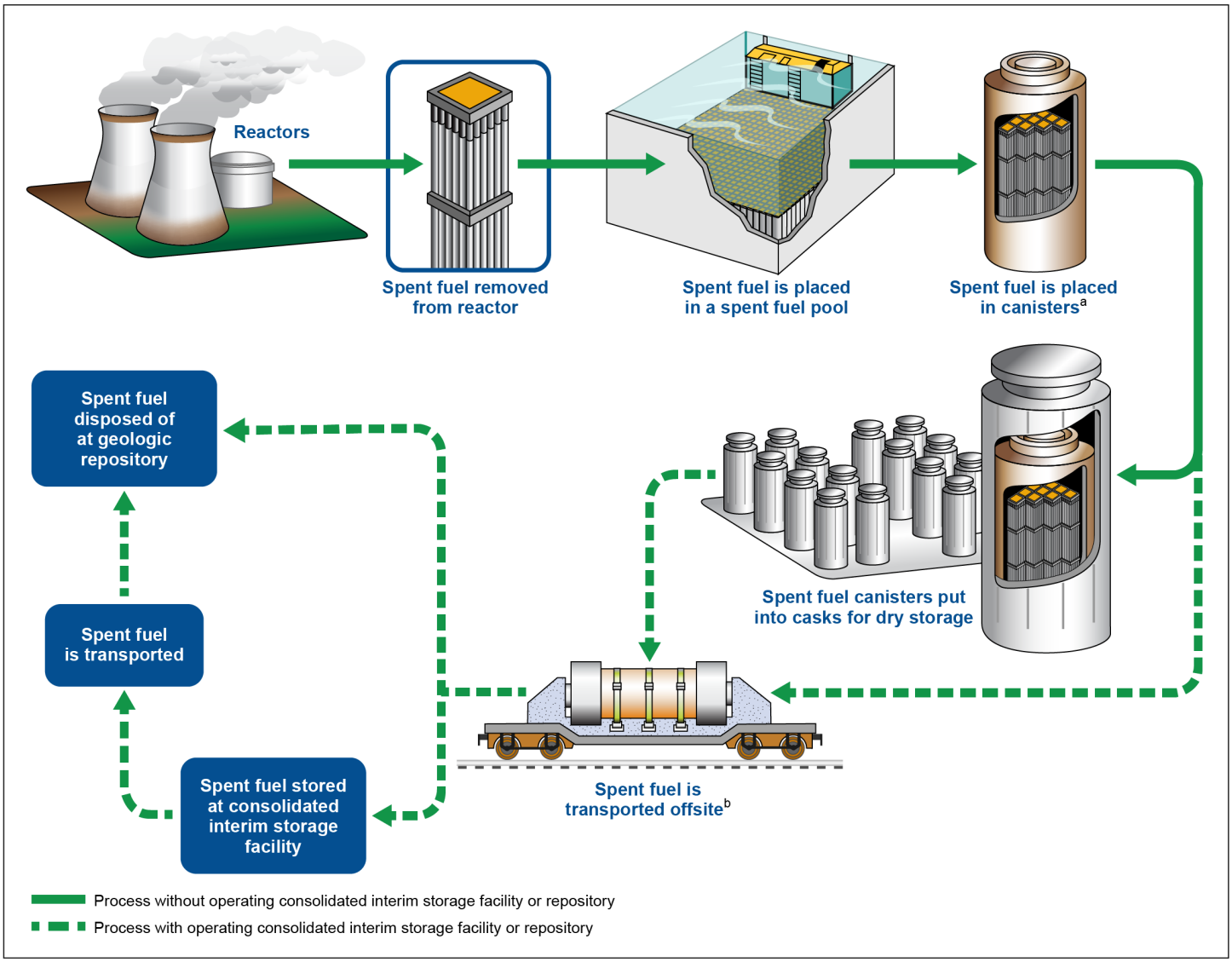
Source: Nuclear Regulatory Commission. | GAO-21-603

Currently, spent fuel will remain in dry cask storage at reactor sites until a consolidated interim storage facility (or facilities) and/or a permanent disposal repository is developed and authorized to accept such fuel.[14] At that time, spent fuel canisters may be transported via truck, rail, and/or barge from reactor sites directly to a permanent geologic repository for disposal or to one or more consolidated interim storage facilities before being transported again to a permanent repository (as shown in fig. 2). However, in the absence of a consolidated interim storage facility or a permanent disposal repository, spent nuclear fuel accumulating at reactor sites may be stored in a variety of different dry storage systems, with no easy way of repackaging the spent fuel should repackaging be required to meet future interim storage, transportation, or disposal requirements.[15]

[14]NRC requires that spent fuel in dry cask storage be stored in approved systems that offer protection from significant amounts of radiation. NRC also requires that storage systems demonstrate compliance with its regulations, including through physical tests of the systems, scaled physical tests, and computer modeling. Once a dry storage system is approved, NRC issues a certificate of compliance for a cask design or a specific license.

[15]Repackaging might be needed in cases in which storage systems in use are not certified for transportation or are not suitable for disposal in a repository. According to the U.S. Nuclear Waste Technical Review Board, repackaging can increase total fuel handling operations; complicates pool operations and increases worker doses if performed at reactor sites; requires the development and deployment of onsite repackaging systems if performed at shut-down reactor sites; and generates additional low-level waste, including discarded dry storage canisters.

Figure 2: Process for Managing Commercial Spent Nuclear Fuel, from Removal and Storage at a Reactor Site to Transportation to a Consolidated Interim Storage Facility or Permanent Repository



Source: GAO. | GAO-21-603

[a]Without an operating consolidated interim storage facility or geologic repository, pools at commercial reactors have largely reached their maximum capacities and cooled fuel therefore generally must be transferred to dry storage. Theoretically, spent fuel removed from a pool could be directly transported to consolidated interim storage facilities or a geologic repository if they existed.

[b]If a consolidated interim storage or permanent geologic repository is developed and authorized to accept commercial spent nuclear fuel, spent fuel canisters may be transported via truck, rail, and/or barge from reactor sites directly to a permanent geologic repository for disposal or to one or more consolidated interim storage facilities before being transported to a permanent geologic repository.

Most commercial nuclear reactors in the United States were built during the 1960s and 1970s and received an initial operating license of 40 years. Most of these reactors received a 20-year license extension, and some have been granted a second license extension, allowing such reactors to operate for up to 80 years. Nevertheless, some of these reactors have begun permanently shutting down and removing spent fuel rods from the reactors' cooling pools. According to the Congressional Research Service, in coming years, many more reactors are expected to follow suit and shut down for a variety of reasons, such as low natural gas prices that make energy generated from nuclear power less economical.[16]

Spent Nuclear Fuel Legislative and Programmatic History

The development of nuclear power in the United States began in the 1950s, peaked in 2012, and has waned in recent years. As previously noted, the disposal of commercial spent nuclear fuel became a federal responsibility with the enactment of the NWPA.[17] The act addressed several key elements of the nation's spent fuel program: siting and constructing a geologic repository for the permanent disposal of spent nuclear fuel; developing consolidated interim storage; and financing the program through the Nuclear Waste Fund.

Geologic Repository

The NWPA directed DOE to investigate potential sites and develop and submit a license application to NRC for the construction of a permanent geologic repository, long considered the safest and most secure option for disposing of commercial spent nuclear fuel.[18] The establishment of such a system for developing and overseeing repositories was a compromise solution that sought to establish a fair and technically sound

[16]According to the Congressional Research Service, as of May 2021, 93 commercial nuclear power reactors were operating at 55 sites in the United States. Two new reactors are under construction. About a dozen more are planned, but with no specific construction dates. Twelve nuclear power reactors permanently closed between February 2013 and April 2021, and seven more are planned for closure through the mid-2020s.

[17]Pub. L. No. 97-425, §§ 111-113, 96 Stat. 2201, 2207-12 (codified as amended at 42 U.S.C. §§ 10131-33). The NWPA also addressed disposal of high-level radioactive wastes from the nation's nuclear weapons program and spent nuclear fuel from naval and other noncommercial origins; as previously noted, such high-level radioactive waste is outside the scope of this report.

[18]Reports by the National Academy of Sciences, including *The Disposal of Radioactive Waste on Land* (Washington, D.C.: September 1957), have identified disposal in a geologic formation as the safest and most secure method of isolating commercial spent nuclear fuel and other types of nuclear waste. Subsequent National Academy of Sciences reports have continued to endorse geologic isolation and have suggested that engineered barriers, such as corrosion-resistant waste containers, can provide additional protection. International consensus also supports geologic disposal.

process for selecting repository locations. The NWPA also required the Secretary of Energy to identify multiple potential sites for repositories. According to the Blue Ribbon Commission on America's Nuclear Future, the act provided for the selection of two repositories to avoid the perception that any one location would be asked to bear the entire burden of disposing of the nation's commercial spent nuclear fuel. The Blue Ribbon Commission reported that, though not stipulated in the legislation itself, it was widely assumed that one repository would be in the western United States and the other in the East.[19] The NWPA also directed NRC to, when approving an application for the first repository, prohibit its capacity from exceeding 70,000 metric tons until a second repository was in operation. This capacity limit helped ensure there would be a second repository, given the anticipated amount of spent nuclear fuel, according to a report from Columbia University's Center on Global Energy Policy.[20]

The NWPA also established a timetable for the characterization of potential sites and the selection of the first and second permanent repositories. Specifically, the President was to recommend a first site to Congress by March 31, 1987, and a second site by March 31, 1990. In May 1986, the Secretary of Energy announced that DOE had narrowed the options for the first repository to three sites: Hanford in Washington, Deaf Smith County in Texas, and Yucca Mountain in Nevada. The Secretary of Energy also announced that DOE was deferring the search for a second repository indefinitely. Following the announcement that DOE was suspending efforts to identify a second repository, in 1987 Congress amended the NWPA and designated Yucca Mountain as the only repository site.

The Yucca Mountain repository has long experienced state and tribal opposition. Nevada state officials have expressed opposition to the Yucca Mountain project, citing concerns about excessive water infiltration, earthquakes, volcanoes, and other technical issues. In addition, Yucca Mountain is located within the Western Shoshone Nation, and according to the Shoshone and Paiute Tribes, they oppose the Yucca Mountain repository on cultural and scientific grounds as a form of environmental racism. In contrast, there was support from local communities within

[19]Blue Ribbon Commission on America's Nuclear Future*, Report to the Secretary of Energy* (Washington, D.C.: Jan. 26, 2012).

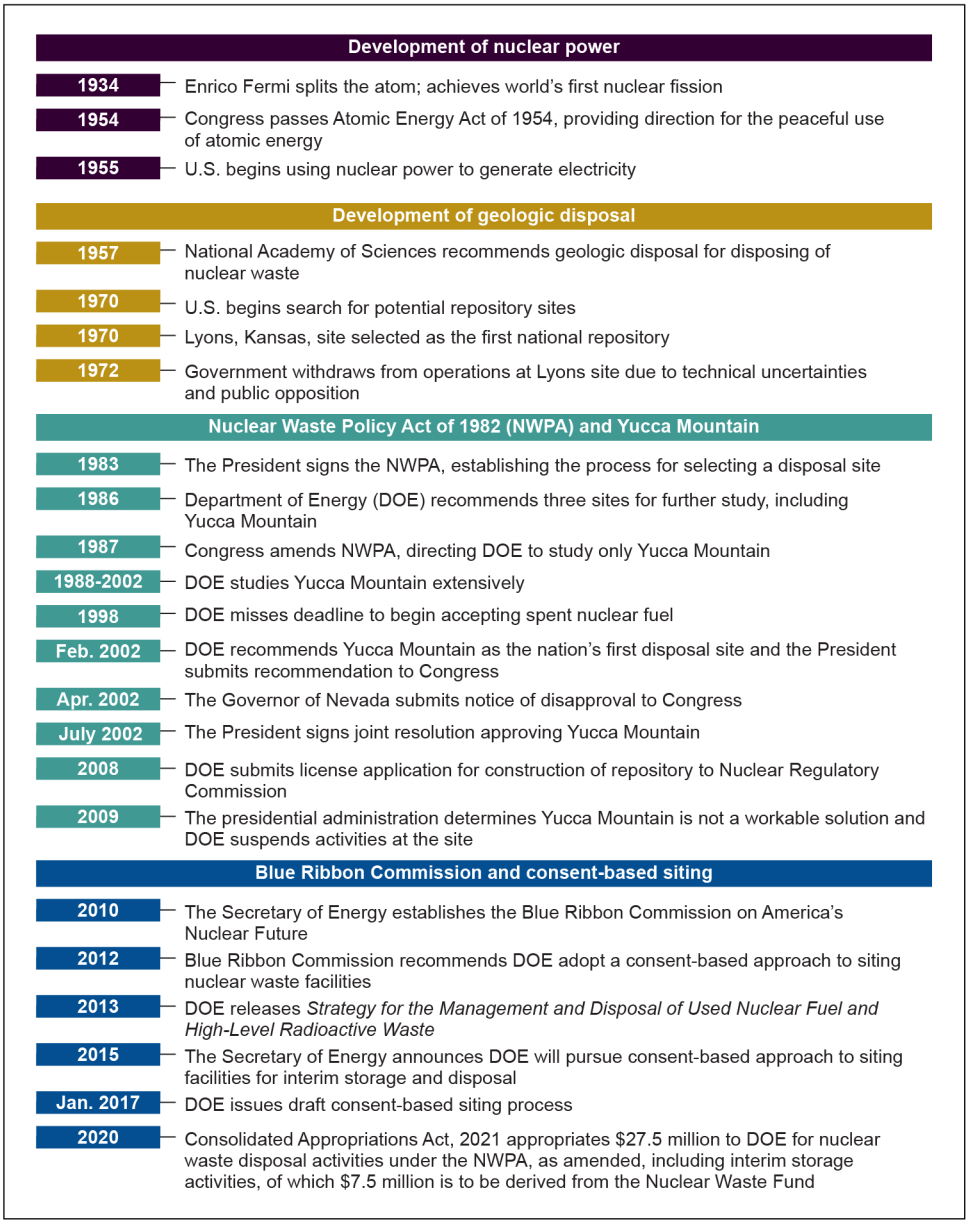
[20]Matt Bowen, *Forging a Path Forward on U.S. Nuclear Waste Management: Options for Policy Makers*, Columbia University Center on Global Energy Policy (New York, N.Y.: January 2021).

Nevada, including from Nye County—the county in which the proposed facility would be located, which supported the repository's development.[21] In 2015, NRC completed its review of DOE's license application for the Yucca Mountain site, as documented in its Safety Evaluation Report, and found that DOE's license application met the regulatory requirements for the proposed repository, with two exceptions: DOE had not obtained certain land withdrawal and water rights necessary for construction and operation of the repository.[22] Amid opposition and litigation, the plans for the Yucca Mountain repository have fluctuated over the past several decades. Figure 3 provides a timeline of key events in the federal government's plans for managing commercial spent nuclear fuel. For more information, see appendix III.

[21]Some social science experts refer to this as the "doughnut effect," in which a local community closest to a proposed site is willing to host a deep geologic repository, but the surrounding region or state oppose the project.

[22]As a result of the Safety Evaluation Report findings, NRC staff recommended that the Commission not authorize construction of the repository until, among other things, these regulatory requirements were met and a supplement to DOE's environmental impact statement was completed. See NRC, *Safety Evaluation Report Related to Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada: General Information,* NUREG-1949 (Washington, D.C.: August 2010). DOE declined to complete the supplement and deferred to NRC. The Commission then directed NRC staff to develop the supplement. This supplement was completed and published in early 2016. See NRC, *Supplement to the U.S. Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* NUREG-2184 (Washington, D.C.: May 2016).

Figure 3: Timeline of Key Events in the Federal Government's Plans for Managing Commercial Spent Nuclear Fuel, 1934–2020



Sources: DOE and GAO. | GAO-21-603

Consolidated Interim Storage

The NWPA also set forth a process for DOE to submit a proposal to construct and operate one or more consolidated interim storage facilities, as part of the U.S. spent nuclear fuel management strategy. These facilities would store commercial spent nuclear fuel in containers designed to cool the fuel and provide shielding from the fuel's radiation. In 1985, DOE recommended converting a federally owned site in Oak Ridge, Tennessee, into an interim storage facility. In January 1986, the governor of Tennessee notified the Secretary of Energy that he opposed the project in the state. Efforts to site the facility in Tennessee ended after the 1987 amendments annulled and revoked DOE's Oak Ridge proposal.

The Nuclear Waste Policy Amendments Act of 1987 provided that DOE could not select a site for consolidated interim storage until the Secretary recommended to the President the approval of a site for the development of a geologic repository, and that DOE could not begin construction of the consolidated interim storage facility until NRC had issued a license for the construction of a repository. This effectively made the development of a federal interim storage facility dependent on the development of a repository at Yucca Mountain. In 2006, a consortium of electric power companies, called Private Fuel Storage, obtained an NRC license for a private consolidated storage facility on the reservation of the Skull Valley Band of the Goshute Indians in Utah.[23] The licensing of Private Fuel Storage was delayed because of state opposition and challenges raised during the license review process, but the license was ultimately issued in 2006. In 2012, Private Fuel Storage requested that NRC terminate the unused license, but subsequently withdrew that request to terminate the license, and NRC accepted that withdrawal. NRC then received license applications for two other privately owned consolidated interim storage facilities—one in Andrews County, Texas, in 2016 and another in Lea County, New Mexico, in 2017. NRC issued a license for the facility proposed in Andrews County, Texas, in September 2021 and expects to make a licensing decision for the facility in Lea County, New Mexico, in January 2022.

The Nuclear Waste Fund

The NWPA established the Nuclear Waste Fund. The NWPA structured it as a separate fund in the U.S. Department of the Treasury, financed

[23]Private Fuel Storage obtained a 20-year license from NRC with an option for a 20-year extension. The license allowed storage of up to 40,000 metric tons of commercial spent nuclear fuel. Though Private Fuel Storage was licensed in 2006 and retains its license, it never began operations.

primarily with receipts from the collection of fees from nuclear utilities and accrued interest to use for certain purposes, including, among other things, the development of geologic repositories.[24] The act authorized DOE to enter into contracts with any person who generates or holds title to spent nuclear fuel—typically utilities, reactor operators, and other owners and generators of spent nuclear fuel. Under the act, such contracts were to provide for DOE to take title to (meaning take custody of) and begin disposing of the contract holders' spent nuclear fuel beginning no later than January 31, 1998. In exchange, generators of spent nuclear fuel under the contracts were to pay a fee on civilian nuclear power generation of 0.1 cents per kilowatt-hour into the newly established Nuclear Waste Fund beginning April 7, 1983. The act provides that the Secretary of Energy is to annually review the amount of the user fee and propose an adjustment, if needed, to ensure full cost recovery.[25] However, the NWPA also provides that DOE may make expenditures from the Nuclear Waste Fund, subject to appropriations, which are subject to triennial authorization. Triennial authorization of appropriations appeared intended to encourage multi-year or lump sum appropriations, according to a background report for the Blue Ribbon Commission.[26]

[24]Specifically, section 302 of the NWPA authorized the Secretary of Energy to enter into contracts with any person who generates or holds title to high-level radioactive waste, or spent nuclear fuel, of domestic origin for the acceptance of title, subsequent transportation, and disposal of such waste or spent fuel. Pub. L. No. 97-425, § 302, 96 Stat. 2201, 2257 (1983) (codified at 42 U.S.C. § 10222). Under the act, such contracts are to provide for payment to the Secretary of certain specified fees. The Nuclear Waste Fund is to consist of such fees, any appropriations made by Congress to the fund, and certain unexpended balances that were available on January 7, 1983, at the time of enactment of the act. The Secretary is authorized to make expenditures from the fund only for purposes of radioactive waste disposal activities under the act, including but not limited to the development of repositories.

[25]Annual user fee assessments look at the programs' life cycle costs and cover a period of at least 125 years. During the early years of the program, the user fee would generate more revenue than needed for the initial costs of the program. This surplus and the interest it generated was expected to cover costs later in the program, as nuclear plants retired from service and no longer paid fees, according to a report from DOE's Office of Civilian Radioactive Waste Management.

[26]DOE did not submit budgets for the U.S. commercial spent nuclear fuel management program triennially, as called for by the NWPA. Instead, the program followed the practice of annual budget requests and annual appropriations as practiced for other DOE programs. See Joseph S. Hezir, *Budget and Financial Management Improvements to the Nuclear Waste Fund: Background Report to the Blue Ribbon Commission on America's Nuclear Future* (May 2011).

According to several reports, the Nuclear Waste Fund was supposed to be isolated from other federal programs, similar to a trust fund, to ensure predictable and adequate funding to implement the commercial spent nuclear fuel program, without competition from other funding priorities or burdening the federal budget. However, comprehensive budget reconciliation measures enacted after 1982 helped reduce the functionality of the Nuclear Waste Fund. For example, the Balanced Budget and Emergency Deficit Control Act of 1985 made the Nuclear Waste Fund subject to a government-wide deficit-reduction process and budget scoring rules that split the fund as if it were two separate accounts—one for receipts and one for expenditures—rather than a single, unified account.[27] Receipts from the nuclear utility fee collections were scored on the mandatory side of the budget, where they were treated like tax revenues and used to offset mandatory spending. Programmatic expenditures were scored on the discretionary side of the budget, where they were subject to limitations on annual discretionary spending to reduce the deficit.[28] Limits on discretionary spending were established statutorily (e.g., Budget Enforcement Act of 1990 and Budget Control Act of 2011[29]) and procedurally (e.g., through congressional budget resolutions and sub-allocations of discretionary spending determined by the Senate and House Appropriation Committees). In 1987, the Office of Management and Budget also eliminated its historical practice of setting separate budget planning targets for the Nuclear Waste Fund, forcing it to compete against other DOE programs within a single

[27]The Balanced Budget and Emergency Deficit Control Act of 1985 created annual deficit limits to establish a balanced budget. Pub. L. No. 99-177, tit. II, 99 Stat. 1038.

[28]The federal budget includes mandatory and discretionary spending. Mandatory spending or “direct spending” refers to funds provided in laws for entitlement programs, such as Social Security, Medicare, and Medicaid. Statutory criteria generally govern mandatory spending. Discretionary spending refers to funds allocated by Congress through annual appropriation acts. Discretionary appropriations are subject to a set of budget enforcement rules and processes that differ from those that apply to mandatory spending.

[29]The Budget Enforcement Act of 1990 established statutory caps to limit discretionary spending through fiscal year 2002. Pub. L. No. 101-508, tit. XIII, 104 Stat. 1388-573. The Budget Control Act of 2011 reinstated discretionary spending limits for fiscal years 2012 through 2021 and required Congress to pass and the President to sign legislation on further deficit reductions. Absent such legislation, discretionary spending was further reduced. Pub. L. No. 112-25, 125 Stat. 240. There will be no discretionary spending limits in fiscal year 2022; it is too early to determine what effect this will have on appropriations for a geologic repository.

DOE budget target for limited discretionary spending, according to a report by DOE's Office of Civilian Radioactive Waste Management.[30]

There have been no new receipts credited to the Nuclear Waste Fund from collections of nuclear utility quarterly fees since the fee was set to zero on May 16, 2014, as a result of litigation in the U.S. Court of Appeals for the District of Columbia Circuit.[31] Specifically, owners and operators of nuclear power plants challenged DOE's collection of user fees, alleging that as long as the federal government had no viable alternative to Yucca Mountain as a repository for nuclear waste, they should not be charged a fee to cover the cost of that disposal. On November 19, 2013, the D.C. Circuit Court of Appeals agreed, ruling that the Secretary of Energy must set the Nuclear Waste Fund user fee to zero until the federal government resumes licensing a geologic repository at Yucca Mountain or Congress enacts an alternative management plan to dispose of commercial spent nuclear fuel. The unappropriated balance of assets and interest credited to the Nuclear Waste Fund over time remains available for appropriation to carry out the purposes of the NWPA, subject to the applicable limitations on federal spending.

Federal Liabilities for Commercial Spent Nuclear Fuel

Federal liabilities for managing commercial spent nuclear fuel reflect the costs that owners and generators of this fuel have paid and are expected to pay in the future because DOE has not met its contractual obligations to begin disposing of the fuel. Utility companies have filed numerous lawsuits in the U.S. Court of Federal Claims alleging that DOE's failure to begin accepting spent nuclear fuel in 1998 constituted a partial breach of contract, and the Court of Appeals for the Federal Circuit has held that the delay constituted such a breach.[32] The Department of Justice pays for such costs on behalf of the federal government, out of the Department of the Treasury's Judgment Fund, under settlement agreements or as a result of final judgments of courts. The Judgment Fund is financed by U.S. taxpayers, and payments out of the fund have no effect on DOE's

[30]Department of Energy, Office of Civilian Radioactive Waste Management, *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program,* DOE/RW-0546 (Washington, D.C.: August 2001).

[31]Nat'l Ass'n of Regul. Util. Comm'rs v. U.S. Dep't of Energy, 736 F.3d 517 (D.C. Cir. 2013).

[32]See, e.g., Maine Yankee Atomic Power Co. v. United States, 225 F.3d 1336, 1343 (Fed. Cir. 2000).

budget.[33] DOE estimates that the total federal liability for litigation related to storing commercial spent nuclear fuel will amount to $39.2 billion, which includes the $8.6 billion already paid out of the Judgment Fund, as well as expected future payments, according to DOE's Fiscal Year 2020 Agency Financial Report.[34] The expected future $30.6 billion in liabilities associated with commercial spent nuclear fuel are not included in DOE's reported environmental liabilities.[35]

Under the NWPA and the standard contract, DOE was to take title to and begin disposing of commercial spent nuclear fuel beginning no later than January 31, 1998. To take title to spent nuclear fuel, DOE would collect spent nuclear fuel from nuclear power plants in the order it came from the reactors—the oldest fuel first—and transport it to a permanent repository for disposal. Under the standard contract, the owners or generators of spent nuclear fuel are responsible for paying the continued storage costs for spent nuclear fuel on-site until such a time that DOE is scheduled to take custody of such fuel for disposal. The majority of the types of costs for which the federal government has been held liable have pertained to dry storage of commercial spent nuclear fuel. Some have been one-time costs, such as the cost of constructing a concrete pad for storing commercial spent nuclear fuel in canisters and dry casks on-site after the fuel was removed from cooling pools. Other storage costs for which the federal government has been held liable are recurring, such as the cost of the canisters themselves.

Department of Energy Assumptions for Liability Estimates

In October 2014, we reported that the Department of Energy's (DOE) estimate of future liability is based on how long DOE expects the federal government to continue to pay for managing commercial spent nuclear fuel.

The estimate in DOE's Fiscal Year 2020 Agency Financial Report assumes activities on a DOE facility to accept spent nuclear fuel (either a consolidated interim storage facility or a permanent repository) will begin by fiscal year 2023. However, DOE has previously extended the dates in its liability estimates several times.

According to DOE officials, costs have to be probable in order to be included in DOE's estimate, and therefore the estimate does not include some uncertainties like repackaging. As a result, the $39.2 billion in total liabilities may be an underestimate.

There may also be additional liabilities associated with the prolonged storage of spent nuclear fuel at reactor sites. For example, in October 2014, we reported that under the terms of the standard contract, DOE does not consider spent nuclear fuel in canisters to be an acceptable form of waste it will receive. Under the terms of the standard contract, DOE is responsible for providing the canisters necessary and, in the case of planning for disposal at Yucca Mountain, DOE designed a canister for transportation, storage, and disposal, but never distributed it. If DOE determines that a special canister is needed in the future, it is not clear who will be responsible for the repackaging, according to agency officials.

Spent nuclear fuel canisters in dry storage may require repackaging if they degrade over time. It is unclear who will ultimately be responsible for covering those costs. Department of Justice officials told us that they expect utilities would argue that the federal government is financially responsible because the repackaging would only be necessary due to degradation over time. However, the issue has not been litigated, according to these officials, and it is unclear who would ultimately be responsible for covering those costs should the issue arise.

Source: GAO; DOE agency financial reports; Department of Justice. | GAO-21-603

[33]The Judgment Fund is a permanent, indefinite appropriation for the payment of judgments against the United States. *See* 31 U.S.C. § 1304.

[34]The owners and generators of commercial spent nuclear fuel continue to submit claims for reimbursement for costs incurred because of ongoing storage of the fuel on reactor sites.

[35]According to DOE, liabilities associated with spent nuclear fuel litigation are not included in the department's environmental liabilities because the environmental liabilities relate exclusively to the cleanup of legacy waste, and therefore the amount owed to commercial utilities is not included. Nonetheless, liabilities associated with commercial spent nuclear fuel create a fiscal exposure for the federal government. DOE records liabilities associated with commercial spent nuclear fuel as contingent liabilities in its agency financial reports. The federal government's environmental liabilities is one area on GAO's list of programs and operations that are high risk because of their vulnerabilities to fraud, waste, abuse, and mismanagement, or that need transformation. DOE is responsible for the largest share of the liability ($512 billion in fiscal year 2020), which is related primarily to retrieving, treating, and disposing of nuclear and hazardous waste. See GAO, *High-Risk Series: Dedicated Leadership Needed to Address Limited Progress in Most High-Risk Areas*, GAO-21-119SP (Washington, D.C.: Mar. 2, 2021).

Key Reports on Managing Commercial Spent Nuclear Fuel

Over the years, a number of task forces, working groups, panels, commissions, and research organizations have issued reports providing recommendations for a path forward for managing the nation's spent nuclear fuel. Many of them have come to similar conclusions. A selection of these reports, along with some of their key findings and recommendations, is provided below.[36]

- **1993 Final Report of the Secretary of Energy Advisory Board Task Force on Radioactive Waste Management.** The Task Force on Radioactive Waste Management was created in April 1991 to analyze how DOE might strengthen public trust and confidence in the commercial spent nuclear fuel management program.[37] In 1993, the Task Force published its final report, with recommendations aimed at helping DOE strengthen public trust and confidence, such as early and continuous stakeholder involvement.[38]
- **2012 DOE Blue Ribbon Commission report.** Following the administration's announcement in 2009 that it planned to withdraw the license application for a geologic repository at Yucca Mountain and study other disposal options, the Secretary of Energy established the Blue Ribbon Commission to consider alternatives to the nation's current institutional arrangements for managing and disposing of commercial spent nuclear fuel and high-level nuclear waste.[39] In January 2012, the Blue Ribbon Commission issued its final report

[36]We list the reports whose findings were most prevalently discussed by the experts we interviewed. We highlight findings and recommendations from those reports based on their relevance to our report's scope.

[37]The Task Force met eight times over a period of 27 months and heard formal presentations from nearly 100 representatives of state and local governments, nongovernmental organizations, and senior DOE headquarters and field office managers. The group also commissioned a variety of studies from independent experts, contracted with the National Academy of Sciences and the National Academy of Public Administration to hold workshops on designing and leading trust-evoking organizations, and carried out one survey of parties affected by DOE's radioactive waste management activities and a second one of DOE employees and contractors.

[38]*Final Report of the Secretary of Energy Advisory Board Task Force on Radioactive Waste Management,* (Washington, D.C.: November 1993).

[39]The Blue Ribbon Commission and its subcommittees met more than two dozen times from March 2010 to January 2012 to hear testimony from experts and stakeholders, to visit nuclear waste management facilities in the United States and abroad, and to discuss the issues identified in its charter. The Blue Ribbon Commission also held five public meetings, in different regions of the country, to hear feedback on its draft report. A wide variety of organizations, interest groups, and individuals provided input to the Blue Ribbon Commission at these meetings and through the submission of written materials.

outlining its findings and providing recommendations.[40] The Blue Ribbon Commission's recommendations focused on ways to sustain the public trust and confidence necessary to see controversial facilities, such as geologic repositories, through to completion. Specifically, the Blue Ribbon Commission recommended that Congress amend the NWPA to authorize a new consent-based siting process that encourages communities to volunteer to be considered to host a new spent nuclear fuel management facility and that includes a flexible and substantial incentive program. The Blue Ribbon Commission also recommended that Congress ensure access to dedicated funding for the spent nuclear fuel management program and establish an independent spent nuclear fuel management organization.

- **2012 RAND Corporation report.** In response to the Blue Ribbon Commission's conclusion that a congressionally chartered federal corporation offers the most promising model for an organization to manage the nation's spent nuclear fuel program, DOE asked the RAND Corporation to examine alternative models for a new management organization. In 2012, the RAND Corporation issued its final report on the issue.[41] Among its findings, the RAND Corporation report concluded that the organizational design of the spent nuclear fuel management program contributed less to the problems encountered in implementation than congressional actions, including the 1987 amendments to the NWPA and changes in budgeting that severely constrained DOE's access to the Nuclear Waste Fund. The report also found that some level of independence from congressional authority is necessary for the spent nuclear fuel management program to be able to enter into a consent-based siting process with tribes, states, and communities.
- **2018 Reset Initiative report.** The Reset Initiative convened spent nuclear fuel management experts and others in 2015 and 2016 to analyze and provide a forum for discussion of the most critical problems and possible solutions to the U.S. spent nuclear fuel

[40]Blue Ribbon Commission on America's Nuclear Future*, Report to the Secretary of Energy*, (Washington, D.C.: Jan. 26, 2012).

[41]RAND Corporation, *Choosing a New Organization for Management and Disposition of Commercial and Defense High-Level Radioactive Materials* (Santa Monica, CA: 2012).

management program.[42] In 2018, Reset published a report summarizing the major issues that were raised during the discussions.[43] Among the report's findings was the importance of consent-based siting, public engagement, access to the Nuclear Waste Fund, and integrating the back end of the nuclear fuel cycle into the spent nuclear fuel management plan. The Reset report also recommended the creation of an independent, utility-owned spent nuclear fuel management organization.

- **2021 U.S. Nuclear Waste Technical Review Board report.** The Nuclear Waste Policy Amendments Act of 1987 established the U.S. Nuclear Waste Technical Review Board to evaluate the technical and scientific validity of DOE's activities, including those for site characterization and those relating to the packaging or transportation of spent nuclear fuel. In April 2021, the board released a report on how to make progress on the U.S. spent nuclear fuel management program.[44] The report synthesizes the current board members' experience reviewing DOE technical programs related to the management and disposal of spent nuclear fuel. The report offers six recommendations, including an iterative, adaptive approach to spent nuclear fuel management—meaning, to remain open to adapting to surprises in the process and to be willing to rethink and adapt previous decisions—and engagement with the public and other stakeholders.

[42]Reset convened five meetings in 2015 and 2016 to discuss potential solutions to spent nuclear fuel management. The meetings consisted of 75 presentations by internationally recognized experts, government officials, legislators, nongovernmental organizations, and members of the public. The meetings were open to the public, interested experts, and scholars.

[43]Stanford University and George Washington University, *Reset of America's Nuclear Waste Management: Strategy and Policy* (Oct. 15, 2018).

[44]U.S. Nuclear Waste Technical Review Board, *Six Overarching Recommendations for How to Move the Nation's Nuclear Waste Management Program Forward* (Arlington, VA: Apr. 30, 2021).

Experts Identified Congressional Actions Needed to Break Impasse over the Disposal of Commercial Spent Nuclear Fuel

According to experts we interviewed, the current impasse over the disposal of commercial spent nuclear fuel will continue unless Congress and then DOE take certain actions. Most of the experts we interviewed agreed that Congress should (1) authorize a new consent-based process for siting, developing, and constructing consolidated interim storage and permanent disposal facilities; (2) develop a program with political insulation and strong leadership; and (3) ensure access to reliable and sufficient funding from the Nuclear Waste Fund. If Congress were to take these actions to break the impasse, Congress could then direct DOE to more fully develop and implement an integrated waste management strategy, which nearly all of the experts we interviewed said was needed. In the meantime, these experts said DOE could prepare for future siting decisions by exploring ways to better engage the public and cultivate trust. Specifically, they stated that DOE could do more to engage the public and cultivate trust by identifying and reviewing lessons learned from other countries' repository-siting efforts, siting the Waste Isolation Pilot Plant in the United States,[45] and academic literature on engaging the public. DOE could then finalize its draft consent-based process for siting, developing, and constructing consolidated interim storage facilities and/or permanent repositories.

Impasse Will Continue Unless Congress Authorizes a New Siting Process and Provides Reliable and Sufficient Funding for Spent Fuel Management, According to Experts

According to experts we interviewed, the impasse over a permanent solution for spent nuclear fuel will continue unless Congress authorizes a new siting process, provides the program with political insulation and strong leadership, and provides reliable and sufficient funding for commercial spent nuclear fuel management. First, most of the experts we interviewed said Yucca Mountain is not a socially or politically viable option for the nation's sole geologic repository. As stated earlier, Congress has not funded activities related to licensing and developing a repository at Yucca Mountain since fiscal year 2010, and the state of Nevada and several Native American tribes have been strongly opposed to a repository at the site for decades. Additionally, the original statutory disposal capacity limit of 70,000 metric tons placed on the first repository (i.e., Yucca Mountain) means that the site is no longer sufficient to hold the existing amount of commercial spent fuel, which, as of the end of 2019, was approximately 86,000 metric tons. Approximately 54,000 additional metric tons are expected to accumulate over the remaining

[45]The Waste Isolation Pilot Plant is the only operating deep geologic repository in the nation and stores defense-generated nuclear waste.

lifetime of existing nuclear power plants, according to data from Gutherman Technical Services, LLC.

Moreover, as previously noted, the NWPA, as amended, directed DOE to focus its efforts on Yucca Mountain as the only permanent geologic repository option.[46] Amendments to the act also precluded DOE from taking steps to develop a consolidated interim storage facility until selection of a site for the development of a geologic repository, effectively tying the development of such an interim storage facility to the development of a repository at Yucca Mountain. Nearly all of the experts we interviewed said the United States should initiate a new siting process that would apply to the siting, development, and construction of consolidated interim storage facilities and permanent geologic repositories for commercial spent nuclear fuel. Most of these experts said the United States should use a consent-based siting process. In 2012, DOE's Blue Ribbon Commission also recommended that Congress amend the NWPA to authorize a new consent-based process for selecting and evaluating repository sites and licensing consolidated interim storage facilities. In order for DOE to initiate a new repository siting process, Congress would need to amend the NWPA to allow DOE to explore the development of options for a geologic repository other than or in addition to Yucca Mountain.

Second, most of the experts we interviewed said the U.S. commercial spent fuel management program, which is overseen by DOE's Office of Nuclear Energy, must be insulated from changes in political priorities, and many said the program must have strong leadership with the right set of skills in order to be successful. Setting up a mechanism to ensure political insulation and strong leadership will require congressional action. DOE's programmatic priorities, including plans for managing commercial spent nuclear fuel, can change every 2 to 4 years with a new Congress or administration. This is reflected in DOE's commercial spent nuclear fuel management program, for example, by DOE's efforts to submit a license application for the Yucca Mountain site in June 2008, followed by the agency's motion to withdraw its license application under a different administration in March 2010. Currently, there is no mechanism to help ensure long-term continuity and consistency in DOE's leadership and programmatic priorities, a critical component for the success of projects

[46]The Nuclear Waste Policy Amendments Act of 1987 called for the orderly phase-out of site-specific activities at all candidate sites other than Yucca Mountain. It also prohibited DOE from conducting site-specific activities with respect to a second repository without authorization and appropriations from Congress for such activities.

spanning multiple decades, according to most of the experts we interviewed. Additionally, several reports we reviewed, including reports from the Blue Ribbon Commission, RAND, and Reset, also stressed the need for the program to have some degree of independence from changes in political priorities.

In addition, many of the experts we interviewed said strong leadership and having the right set of skills are critical to the success of DOE's commercial spent nuclear fuel program. According to most of the experts we interviewed, DOE has historically not had the leadership or skills needed for effective public and stakeholder engagement. We previously reported that DOE took some steps to engage the public on the Yucca Mountain repository, but we found the level of engagement was insufficient to sustain public support.[47] As a result, we recommended that DOE develop and implement a coordinated outreach strategy for providing information to specific stakeholders and the public on federal activities related to managing spent nuclear fuel.[48] Most of the experts we interviewed said public and stakeholder engagement is critical to a successful commercial spent nuclear fuel program. Several of the experts suggested that a variety of skills—including experience in the social sciences, conflict resolution, and negotiations—are necessary for the success of the program. DOE officials told us that they could hire staff with the appropriate skill sets for public engagement, such as social scientists. In addition, some of the experts said having a board of directors to oversee and provide guidance to the program could help mitigate against changes in political priorities by providing a range of views and continuity in leadership. A couple of these experts suggested giving board seats to representatives of key stakeholder groups—such as tribes, states, and nuclear utilities—could help ensure a range of stakeholders' views are represented.

Lastly, nearly all of the experts we interviewed said reliable and sufficient funding was key to the success of a spent nuclear fuel program. Several reports, including reports from the Blue Ribbon Commission, Reset, and

[47]GAO-15-141.

[48]DOE agreed with our recommendation and created dedicated public outreach positions and opened social media accounts to post presentations, videos, and blogs related to spent nuclear fuel management. As a result, we closed the recommendation as implemented in August 2021.

GAO,[49] have also concluded that a more reliable funding mechanism would enhance DOE's ability to manage commercial spent nuclear fuel. The NWPA established the Nuclear Waste Fund as a self-financing mechanism based on a user-pays principle to provide a stable source of funding for developing, constructing, and operating a geologic repository for the disposal of commercial spent nuclear fuel, according to several reports. However, according to most of the experts we interviewed, the Nuclear Waste Fund does not work as intended. Comprehensive budget reconciliation measures enacted after the fund's creation limited access to the fund. For example, the commercial spent nuclear fuel program must compete with other DOE priorities for limited federal funding each year, instead of being isolated from the federal budget process.

Most of the experts we interviewed said Congress should remove the Nuclear Waste Fund from the annual appropriations process to allow the fund to function as originally intended, including funding the spent nuclear fuel program based on the life cycle costs of developing a geologic repository and not competing with other federal programs. From fiscal year 1983 through 2010, Congress often appropriated less than DOE's requested budget for spent nuclear fuel management, leading to budget shortfalls and missed deadlines.[50] We have previously reported that annual DOE appropriations for spent nuclear fuel management have varied by as much as 20 percent from year to year, and the average annual difference between the agency's budget request and DOE appropriations has been $90 million.[51]

Many of the experts we interviewed said unreliable funding created planning inefficiencies in the Yucca Mountain program, such as greater programmatic costs and lower morale among DOE staff. For example, according to one expert, insufficient funding for the Yucca Mountain project created the potential for staff turnover and delays. As another expert put it, one 5-year project is better than five 1-year projects when it comes to large projects that span multiple decades. Two of the experts said unreliable funding also contributes to the public's distrust in the

[49]GAO, *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned,* GAO-11-229 (Washington, D.C.: Apr. 8, 2011).

[50]Congress has not appropriated funds for Yucca Mountain since fiscal year 2010.

[51]GAO-11-229.

federal government's ability to manage spent nuclear fuel because DOE cannot spend the money needed to advance the program.

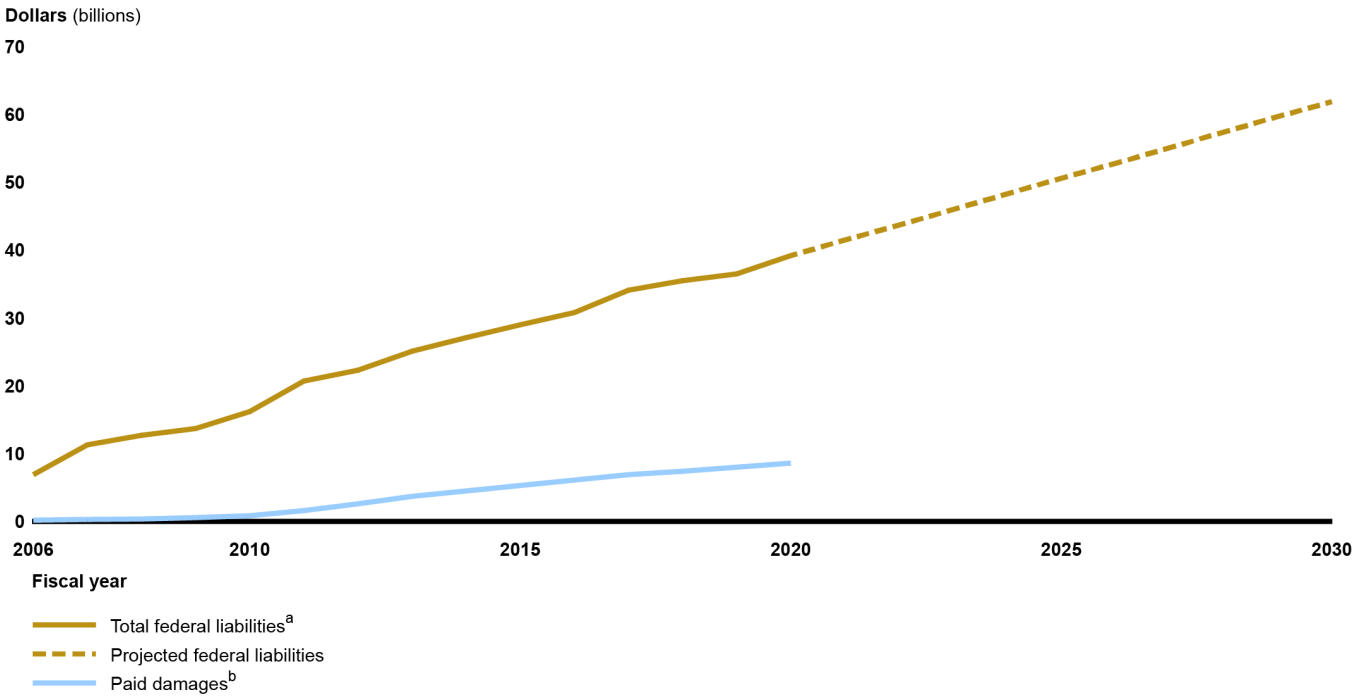
Most of the experts we interviewed said that without congressional action, the impasse over a solution for the nation's spent nuclear fuel will continue. They also highlighted concerns related to increasing costs; environmental, health, and security risks; climate change; and an ethical responsibility to future generations.

- **Costs.** Long-term costs to the federal government for commercial spent nuclear fuel come from liabilities related to paying utilities to store spent fuel at reactor sites and the future costs of building a repository to dispose of such fuel. Federal liabilities for storing spent nuclear fuel at reactor sites are growing as the amount of spent nuclear fuel stored at reactor sites continues to accumulate (see fig. 4). At the same time, DOE is not collecting fees to support the Nuclear Waste Fund, which could result in insufficient funds for developing a permanent repository.[52] The costs associated with disposal of spent nuclear fuel increase with time, according to a 2019 Sandia National Laboratories report.[53] Most of the experts we interviewed expressed concerns about the rising costs of continuing to store spent nuclear fuel on-site at reactors. As previously noted, these costs are borne by the U.S. taxpayer.

[52]Even if the Nuclear Waste Fund fees are reinstated, the number of nuclear reactors generating electricity and that would be paying into the Nuclear Waste Fund has decreased in recent years as facilities shut down. This trend is likely to continue in the near term.

[53]Sandia National Laboratory, *Comparative Cost Analysis of Spent Nuclear Fuel Management Alternatives,* SAND2019-6999 (Albuquerque, NM: June 2019).

Figure 4: Department of Energy's Commercial Spent Nuclear Fuel Total Liability Estimate, from Fiscal Years 2006 through 2020, and Straight-Line Projections to Fiscal Year 2030



Source: GAO analysis of Department of Energy financial reports. | GAO-21-603

Notes: Federal liabilities for managing commercial spent nuclear fuel reflect the costs that owners and generators of this fuel have paid and are expected to pay in the future to store the fuel because the Department of Energy (DOE) has not met its contractual obligations to begin disposing of this fuel by January 31, 1998. Projected federal liabilities (fiscal years 2021 through 2030) are based on the average annual dollar increase for paid liabilities from fiscal years 2005 through 2020. Liabilities are reported in nominal dollars, which are not adjusted for inflation.

The nuclear industry estimated that damages (liabilities) for all utilities with which DOE has contracts ultimately would be at least $50 billion, according to DOE's annual financial reports. DOE believes that the industry's estimate is highly inflated and that the federal government's ultimate liability is likely to be significantly less than that estimate based on settled suits.

[a]DOE's total federal liability estimate assumes activities on a DOE facility (either a consolidated interim storage facility or permanent repository) will begin by fiscal year 2023. This estimate assumes that acceptance of commercial spent nuclear fuel will begin no later than the time frames contained in the Nuclear Waste Policy Act of 1982 (NWPA), as amended, and the Yucca Mountain license application. According to DOE's Fiscal Year 2020 Agency Financial Report, this assumption is reasonable as long as Congress either does not change existing law or amends the NWPA to allow DOE to pursue the development of consolidated interim storage facilities.

[b]Under the terms of settlement agreements or as a result of court decisions, the federal government paid almost $9 billion to utilities for delay damages these utilities incurred through September 30, 2020, related to DOE's delay in accepting commercial spent nuclear fuel for disposal, according to DOE's Fiscal Year 2020 Agency Financial Report. The Department of Justice pays the costs for such settlements on the behalf of the federal government, out of the Department of the Treasury's Judgment Fund.

- **Environmental, health, and security risks.** NRC has analyzed the impacts of on-site dry cask interim storage for periods of at least 60 years beyond the licensing period of a reactor, as well as for successive 100-year periods after the first 60 years. NRC has concluded that spent fuel can be adequately protected and safely stored in the short term until a repository is available or indefinitely, should it be necessary to do so,[54] and two of the experts we interviewed said dry casks may be safely stored for up to 100 years. However, the longer it takes the federal government to resolve the current impasse and develop a solution for the permanent disposal of commercial spent nuclear fuel, the greater the potential risk to the environment and public health, or of security incidents associated with temporary on-site storage, according to some of the experts we interviewed. Specifically, according to many of the experts we interviewed, the safety of long-term dry cask storage is unknown, and the risks, such as environmental and health risks, of on-site storage increase the longer the fuel is stored there.[55] Several of the experts pointed to security risks of continued on-site storage, which relies on government institutions such as DOE and NRC to provide oversight of the management of dry casks to ensure they are secure.[56]
- **Climate change.** Nuclear power can play an important role in reducing carbon emissions from the electricity sector. However, most of the experts we interviewed said the impasse over a solution for managing spent nuclear fuel has a negative impact on the nuclear energy industry. For example, several states have laws prohibiting new nuclear power plants until additional progress is made on

[54]*See* 79 Fed. Reg. 56,238 (Sep. 19, 2014) (codified at 10 C.F.R. pt. 51); Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel: Final Report, Volume 1 (NUREG-2157), at iii, xxx; *DTE Electric Co.* (Fermi Nuclear Power Plant, Unit 3), CLI-15-4, 81 NRC 221 (2015).

[55]According to NRC documentation, potential risks could result from degradation or damage to storage canisters. For example, chloride-induced stress corrosion could crack the welded stainless steel canisters. Chloride-induced stress corrosion is not a credible risk during the first 20 years of operation because of the long time needed for such cracks to grow through the stainless steel canister wall, according to NRC staff research. After 20 years, aging management plans take into account potential chloride-induced stress corrosion cracking.

[56]Potential security risks include attempted sabotage or theft of radioactive material from dry storage casks. According to NRC documentation, the potential threat level and the consequences of such an event dictate the security requirements at NRC-licensed facilities. There have been no known or suspected attempts to sabotage or steal radioactive material from dry cask storage sites or direct attacks to on-site storage facilities.

managing nuclear waste.[57] As such, not having a solution for disposal has implications for nuclear energy more broadly and could inhibit future development of nuclear power plants as a carbon-free energy source.[58]

- **Ethics.** Several of the experts we interviewed said the current generation has an obligation to develop a solution for the disposal of nuclear waste and that it would be unethical to leave future generations responsible for addressing the problem. For example, one expert said the generation that benefited from nuclear energy and created the waste has the responsibility to find a safe solution for disposing of such commercial spent nuclear fuel rather than leaving the problem for future generations.

If Congress Authorizes DOE to Consider New Disposal Options, DOE Could More Fully Develop and Implement an Integrated Waste Management Strategy

If Congress amends the NWPA to allow DOE to explore disposal options other than or in addition to the Yucca Mountain repository, DOE could more fully develop and implement an integrated waste management strategy. DOE's 2021 Strategic Vision calls for the establishment of an integrated waste management system to address the nation's commercial spent nuclear fuel inventory,[59] and nearly all of the experts we interviewed said the United States needs an integrated waste management strategy. Experts we interviewed discussed various elements of an integrated waste management strategy—specifically, plans for the interim storage, transportation, and permanent disposal of commercial spent nuclear fuel.

Regarding interim storage, nearly all of the experts we interviewed cited advantages of consolidated interim storage. Specifically, most of the experts said consolidated interim storage could produce cost savings by removing spent nuclear fuel from reactor sites. However, the cost savings associated with consolidated interim storage depend on a variety of

[57]According to the National Conference of State Legislatures, 13 states have placed restrictions on the construction of new nuclear power facilities: California, Connecticut, Hawaii, Illinois, Maine, Massachusetts, Minnesota, New Jersey, New York, Oregon, Rhode Island, Vermont, and West Virginia.

[58]Specifically, nuclear power plants emit no carbon dioxide during operations and, unlike many renewable sources of energy, the power they generate is accessible on demand. Nuclear energy has accounted for about 20 percent of the electricity generated in the United States since 1990. Nuclear energy also provided 52 percent of the U.S.'s carbon-free electricity in 2020, making it the largest domestic source of clean energy.

[59]Department of Energy, *Office of Nuclear Energy Strategic Vision* (Washington, D.C.: January 2021).

factors, including (1) the time it takes to establish a permanent repository, according to a 2016 report from DOE's Oak Ridge National Laboratory,[60] and (2) when DOE takes title to the spent nuclear fuel. For example, two private entities have submitted license applications for consolidated interim storage facilities, but it is unclear whether these private entities could take title to the commercial spent nuclear fuel and therefore provide cost savings to the federal government. In addition, most of the experts we interviewed said that in order for a consolidated interim storage facility to be viable, the United States would need to have a plan for a permanent geologic repository.[61]

Regarding transportation, several of the experts said any integrated waste management plan must take into account issues related to transporting spent fuel from reactor sites to an interim storage facility or geologic repository. However, according to one expert we interviewed, some transportation issues associated with consolidated interim storage have not been considered because spent nuclear fuel management is compartmentalized. According to the U.S. Nuclear Waste Technical Review Board, many owners of nuclear reactors are storing spent nuclear fuel in larger canisters because they determined such canisters were more economical than smaller canisters; however, there is no standardized storage canister size or design. Factors related to utilities' storage decisions, such as canister size and condition of the fuel inside canisters, will affect transportation options for spent nuclear fuel. The U.S. Nuclear Waste Technical Review Board also reported that some of the canisters used for on-site dry storage of spent nuclear fuel are licensed for both storage and transportation, while others are only licensed for storage.[62] One expert we interviewed said the ability to transport spent nuclear fuel to a consolidated interim storage facility or a repository could

[60]Oak Ridge National Laboratory, *Cost Implications of an Interim Storage Facility in the Waste Management System*, FCRD-NFST-2015-000648 Rev. 1; ORNL/TM-2015/18 (Oak Ridge, TN: September 2016).

[61]In addition to the legal limitations on siting a federal consolidated interim storage facility before siting a geologic repository, many experts raised concerns that efforts to site and develop a consolidated interim storage facility would distract from efforts to site and develop a permanent geologic repository.

[62]U.S. Nuclear Waste Technical Review Board, *Six Overarching Recommendations to Move the Nation's Nuclear Waste Management Program Forward* (Arlington, VA: April 2021).

Deep Borehole Disposal

According to the Department of Energy, the deep borehole disposal concept has been around since the 1950s. This approach consists of drilling a borehole thousands of feet deep, placing waste canisters in the lower part of the borehole, and sealing the upper part of the borehole with bentonite and concrete seals.

In more recent years, the concept of lateral boreholes has been explored. With this approach, the drill hole would begin with a vertical access section that goes down between a few thousand feet and a few miles, depending on the geology. The drill hole then gradually curves over a distance of typically 1,000 feet, until the hole is nearly horizontal. The horizontal section is meant to be the disposal section of the borehole.

Source: DOE; Deep Isolation. | GAO-21-603

Reprocessing

As we have previously reported, reprocessing is the industrial process of recovering plutonium and uranium from spent nuclear fuel, which can then be recycled for use in new fuel.

However, reprocessing spent nuclear fuel also generates waste products that must be stored until transfer to a deep geologic repository for permanent disposal. For example, in the 1960s and 1970s, a commercial facility at West Valley in New York State reprocessed spent nuclear fuel from commercial and defense reactors, and the wastes separated during operation of the plant remain on-site because there are no facilities authorized to accept them.

For more information on the West Valley Demonstration Project, see GAO, *Nuclear Waste: Congressional Action Needed to Clarify a Disposal Option at West Valley Site in New York,* GAO-21-115 (Washington, D.C.: Jan. 13, 2021).

There are no commercial reprocessing facilities currently operating in the United States.

Source: GAO. | GAO-21-603

prove that the system works and help build confidence in the federal government's program for managing spent nuclear fuel.

Regarding disposal, most of the experts we interviewed said a permanent geologic repository is necessary for the successful disposal of commercial spent nuclear fuel, regardless of whether other options, such as deep borehole disposal, fuel reprocessing, advanced nuclear reactors, or other technologies, become viable. Two of the experts said it would be advantageous to develop a waste management system that plans for alternative technologies to complement permanent geologic disposal. Many of the experts said changing the narrative surrounding commercial spent nuclear fuel management could facilitate public support of a permanent geologic repository.

The United States currently has an ad hoc system for managing spent nuclear fuel. Specifically, there is no standardized strategy for storing fuel on-site at reactors and no standard storage canister. Several of the experts told us that the current system is compartmentalized and cited benefits to developing a more holistic approach to the various aspects of commercial spent fuel management. As one expert put it, in an ideal world, for interim storage, spent fuel would be packaged only once, not twice, in order to minimize the number of times that fuel rods would be handled. Used rods and the spent fuel could be put in dry cask storage, which would work with the transportation system and long-term repository. But, according to DOE officials, it is nearly impossible to design a standardized canister without knowing the future requirements for interim storage or repository disposal. As a result, spent fuel is stored using a variety of different technologies that will have implications for final disposal.

DOE cannot develop and implement an integrated waste management strategy until Congress provides direction on the path forward for commercial spent fuel management, such as the location and number of geologic repositories and the role of consolidated interim storage. In 2013, DOE developed an integrated waste management strategy but could not fully implement it without authorization from Congress because, according to the strategy, it included elements not authorized under current law. DOE stopped using this strategy altogether in 2017 and has not developed a new plan. However, in fiscal year 2021, Congress appropriated $27.5 million to DOE for nuclear waste disposal activities, including interim storage activities. According to agency officials we interviewed, DOE can design certain elements of a consolidated

Advanced Nuclear Reactors

An advanced nuclear reactor is generally defined as a nuclear fission reactor with significant improvements over the most recent generation of nuclear fission reactors (42 U.S.C. § 16271(b)(1)).

Such reactors include light water reactor designs that are far smaller than existing reactors, as well as concepts that would use different moderators, coolants, and types of fuel. For more information on advanced reactors, see GAO, *Technology Assessment: Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts*, GAO-15-652 (Washington, D.C.: July 28, 2015).

Many of these advanced designs are considered to be small modular reactors—reactors with electric generating capacity of less than 300 megawatts, in contrast to an average of about 1,000 megawatts for existing commercial reactors.

According to the Congressional Research Service, unconventional reactors may offer some spent fuel management advantages over existing commercial reactors. Fast reactors, and some other unconventional reactors, could be more effective at destroying actinides compared with commercial reactors. Actinides are responsible for the vast majority of the radioactive hazard that remains in nuclear waste after the first few centuries.

Source: GAO; Congressional Research Service. | GAO-21-603

interim storage facility, but it will not be able to begin construction without an active repository program.

Finally, in the absence of an integrated waste management strategy, DOE is unable to reasonably estimate the total life cycle costs of managing spent nuclear fuel or ensure the Nuclear Waste Fund is sufficient to cover the cost of a permanent repository. As previously noted, following several federal court decisions, the nuclear waste fee collection under the Nuclear Waste Fund was set to zero.[63] Without a clear strategy and programmatic cost estimates, DOE may not be able to resume collection of nuclear waste fees, and it is unclear whether the Nuclear Waste Fund will be sufficient to fund the construction of a permanent geologic repository.[64] As of September 2020, the Nuclear Waste Fund had a balance of almost $43 billion and had accrued an average of $1.4 billion in interest per year over the last 10 years. Interest will continue to accrue on the fund, with the amount of interest depending on the balance of the Nuclear Waste Fund from year to year and the interest rates on Treasury securities held by the Nuclear Waste Fund.[65] According to a 2019 Sandia National Laboratories report, estimated costs for disposal of the amount of accumulated spent nuclear fuel in 2031—which assumed licensing of the Yucca Mountain repository restarted in 2019, repository construction authorization from NRC in 2025, and initial spent fuel receipts and repository operations began in 2031—ranged from $75 billion to $119 billion. By comparison, the report estimated that costs to be paid out of the Nuclear Waste Fund for disposal of the amount of accumulated spent nuclear fuel in 2117—which assumed repository construction authorization from NRC in 2111 and initial spent fuel receipts and repository operations beginning in 2117—would range from $83

[63]Nat'l Ass'n of Regul. Util. Comm'rs v. U.S. Dep't of Energy, 736 F.3d 517 (D.C. Cir. 2013); Nat'l Ass'n of Regul. Util. Comm'rs v. U.S. Dep't. of Energy, 680 F.3d 819 (D.C. Cir. 2012).

[64]As previously mentioned, fewer owners of nuclear reactors generating electricity will be paying into the Nuclear Waste Fund in the near future as a number of these reactors shut down.

[65]The amount in the Nuclear Waste Fund depends on whether the nuclear waste fee continues to be set at zero or it is raised, and on whether Congress appropriates funds from the Nuclear Waste Fund.

billion to $127 billion.[66] This means that the sufficiency of the Nuclear Waste Fund to cover the costs of a permanent repository depends on when construction of the repository begins, among other things. If the Nuclear Waste Fund is not sufficient to cover these disposal costs, and the nuclear waste fee remains set to zero, the American taxpayer may ultimately pay the additional costs.

Independent of Congressional Action, DOE Could Prepare for Future Siting Decisions by Better Engaging the Public and Finalizing its Consent-Based Process

Independent of congressional action, DOE could take steps to lay the groundwork for future congressional decisions related to commercial spent nuclear fuel management. Specifically, DOE could do more to engage the public and cultivate trust for siting an interim storage facility or geologic repository. Most of the experts we interviewed said the public does not trust DOE when it comes to managing spent nuclear fuel. To mitigate the low levels of trust, most of the experts we interviewed recommended that DOE identify and review best practices for facilitating public engagement and cultivating public trust, such as lessons learned from siting repositories in other countries, siting the Waste Isolation Pilot Plant in the United States, and literature on engaging the public.

In 2015, DOE began efforts to better engage the public and cultivate trust. Specifically, DOE initiated a national-level dialogue with stakeholders and reviewed findings and recommendations from expert groups and international experience to find a willing host community for a geologic repository. Based on these efforts, in January 2017 DOE released a draft consent-based process for siting consolidated interim storage facilities and permanent geologic repositories.[67] DOE's draft consent-based

[66]These estimates are in 2018 dollars and are not adjusted for inflation. They include the costs to be paid out of the Nuclear Waste Fund for scenarios in which disposal of spent nuclear fuel begins in 2031 and 2117, respectively. Total costs, which include costs paid out of the Nuclear Waste Fund, costs paid out of the Judgement Fund, and costs paid out of other resources, range from about $102 billion to $139 billion in the 2031 disposal scenario, and from about $141 billion to $168 billion in the 2117 disposal scenario. The estimates also use DOE's 2008 Total System Life Cycle Costs assumption of an entire future disposal inventory of 109,300 metric tons of spent nuclear fuel. See Sandia National Laboratories, *Comparative Cost Analysis of Spent Nuclear Fuel Management Alternatives,* SAND2019-6999 (Albuquerque, NM: June 2019).

[67]Department of Energy, *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste* (Jan. 12, 2017).This effort was in response to the agency's 2013 Management Strategy, which called for "a phased, adaptive, and consent-based approach to siting and implementing a comprehensive management and disposal system" for spent nuclear fuel and high-level radioactive waste. Department of Energy, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (January 2013).

process identified and defined 11 general design principles (see table 1). Many of the experts we interviewed said DOE was on the right track for engaging the public with its draft consent-based siting process; however, the agency stopped work on that process in 2017. Several of the experts we interviewed said that prior to restarting work on a consent-based siting process, DOE should ask the public to define the spent nuclear fuel problem and identify solutions, similar to Canada's approach when restarting its spent nuclear fuel program.[68]

Table 1: Department of Energy's General Design Principles for a Consent-Based Siting Process

Principle	Description
Prioritization of safety	The highest priority will be to site, design, construct, operate, and close nuclear fuel management facilities in a safe and secure manner that is protective of human health and the environment.
Environmental responsibility	The siting process will support the development, construction, operation, and closure of facilities that successfully isolate radioactive materials from the environment and use best practices with respect to rigorous planning, implementation, and monitoring.
Regulatory requirements	The siting process will support the development of facilities that meet or exceed applicable regulatory requirements. Regulatory requirements will be applied rigorously and transparently.
Trust relationship with Indian tribes	The siting process will respect tribal sovereignty and self-determination, lands, assets, resources, and treaty and other federally recognized and reserved rights. The process will take into account siting impacts on sacred tribal lands and other areas and resources of religious or cultural significance.
Environmental justice	The process will pursue fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income. The process will also embrace environmental justice principles and comply with federal requirements and guidance on these issues.
Informed participation	Consent is not meaningful unless it is informed. This means that the implementing organization will share information and provide financial and technical resources to communities as needed to enable effective participation and provide for informed decision-making.
Equal treatment and full consideration of impacts	The siting process will be conducted in a manner that is considerate of parties who are or may reasonably be affected, identifies and shares information about potential impacts, and makes explicit the role of fairness and equity considerations in its decision-making.
Community well-being	Communities will want to weigh the potential opportunities and risks of hosting a facility, including the social, economic, environmental, and cultural effects—both positive and negative—it may have on the community. To ensure that the siting process is fair and durable, consideration of all these effects and benefits will be integral to the siting process.

[68]In 2002, the Canadian Parliament passed the Nuclear Fuel Waste Act, which required Canada's Nuclear Waste Management Organization to study approaches for the safe, long-term management of spent nuclear fuel, and to recommend a preferred approach to the Government of Canada, according to Canada's Nuclear Waste Management Organization website. The 3-year study assessed management approaches from a variety of perspectives—ethical, social, economic, and technical—based on expert advice, guidance from the Advisory Council, and consultation with indigenous communities and the public.

Principle	Description
Voluntariness/ right to withdraw	Participation in the consent-based siting process will be voluntary. Further, a community that volunteers to be considered for hosting a nuclear waste management facility will reserve the option to reconsider and withdraw itself from further participation up to the point that a binding agreement has been signed. Provisions specifying when and on what grounds agreements could be terminated or amended beyond that point could be negotiated as part of the agreement.
Transparency	The siting process will be open to input throughout, and transparent with respect to how decisions are made. Every effort will be made to share information and input with all participants in the process and explain how this information and input is being considered or applied.
Stepwise and collaborative decision-making that is objective and science-based	The process will be implemented in discrete, transparent, and easily observed and evaluated steps, in consultation with the public, interested stakeholders, and affected parties. Decisions will be based on sound science and siting considerations and regulatory requirements will be applied rigorously and transparently. The siting process will recognize the value of supporting robust participation, encouraging multiple applications, and keeping options open, especially in the early phases of the siting process.

Source: Department of Energy's 2017 Draft Consent-Based Siting Process. | GAO-21-603

DOE's draft consent-based siting process includes elements that nearly all of the experts we interviewed agreed are critical for an effective siting process. Other countries furthest along in the siting process—such as Canada, Finland, and Sweden—have also incorporated these elements to engage the public and cultivate trust.[69] One expert said the elements to build trust are necessary conditions for but not a guarantee of success. Another expert said building trust and confidence is not a menu to choose from, where you can pick some things and ignore others; you cannot leave one ingredient out to make a recipe, and it is the same thing with building trust and confidence—you must do all of it. Table 2 summarizes elements for an effective siting process, as identified by the experts we interviewed, selected countries, and DOE's draft consent-based siting process.

[69]Canada's Nuclear Waste Management Organization completed a 3-year-long dialogue with the public to develop a path forward for spent nuclear fuel management and is now narrowing down interested communities to identify a single site for a geologic repository. Finland selected a site for its deep geologic repository and began construction on the disposal facility in 2016. Posiva, Finland's waste management organization, expects to operate the repository in 2023. SKB, Sweden's waste management organization, began its siting process in the 1990s and selected a final site in 2009. SKB expects to begin construction on the disposal facility in 2022 and to begin accepting spent nuclear fuel in 2028 or 2029.

Table 2: Elements for an Effective Siting Process According to Experts GAO Interviewed, Selected Countries, and the Department of Energy's Draft Consent-Based Siting Process

Elements for an effective siting process	Experts GAO interviewed	Canada	Finland	Sweden	Waste Isolation Pilot Plant[a]	Department of Energy's draft consent-based siting process
Early engagement and outreach	✓	✓	✓	✓	✓	✓
Key roles of tribes and states	✓	✓	n/a	n/a	✗	✓
Phased adaptive approach	✓	✓	✓	✓	✗	✓
Voluntariness and the right to withdraw	✓	✓	✓	✓	✓	✓
Informed consent	✓	✓	✓	✓	✓	✓
Tailored community benefits	✓	✓	✓	✓	✓	✓

Legend:
✓ = yes
✗ = no
n/a = not applicable

Source: GAO analysis of expert responses and the Department of Energy's draft consent-based siting process. | GAO-21-603

[a]The Waste Isolation Pilot Plant is the only operating deep geologic repository in the U.S. and stores defense-generated nuclear waste.

Specifically:

- **Early engagement and outreach.** Most of the experts we interviewed said early and frequent public engagement is critical for cultivating trust. Further, many of the experts and all of the officials we interviewed from the waste management organizations in Canada, Finland, and Sweden said engaging the public requires substantial amounts of time and the right skill sets. For example, Canada, Finland, and Sweden spent decades educating and engaging with the public to determine how communities want to engage during the process and how they want the siting process to work.[70] One official said a management organization must demonstrate it listened to the public by incorporating their views into the siting process or explaining the reasons for not incorporating them. Cultivating trust also requires the appropriate people with social science, communication, and technical skills to work with the public, according to all of the officials we interviewed from the waste management organizations in Canada, Finland, and Sweden. For example, the management organizations in

[70]Canada spent almost 20 years, Finland spent about 17 years, and Sweden spent over 30 years engaging with the public prior to selecting a site for a permanent geologic repository, according to officials from the waste management organizations in these countries.

Canada, Finland, and Sweden each had their own public engagement departments with social scientists and communications staff to develop engagement strategies and work with the public during the siting process. Selected engineers, with the ability to simplify and explain complex technical issues to non-engineers, were also present at open houses and meetings to answer the public's questions. DOE's stepwise collaborative decision-making draft design principle calls for the process to be implemented in discrete, transparent, and easily observed and evaluated steps, in consultation with the public, interested stakeholders, and affected parties.

- **Key roles of tribes.** When working with tribal nations, several experts said it is essential to have government-to-government consultation because of federally recognized tribes' inherent sovereignty.[71] According to one expert and two stakeholders we interviewed, inconsistent treatment of tribes was one of the problems surrounding the siting of a repository at Yucca Mountain. For example, the expert said that at times there was government-to-government consultation, but at other times, the federal government engaged with tribes as part of its general engagement with the public. Many of the experts we interviewed said Canada's efforts to integrate indigenous nations' interests, concerns, and counsel from the beginning of their siting process is a good model to follow for cultivating trust. Specifically, Canada's Council of Elders and Youth is an advisory body that provides counsel on the application of Indigenous Knowledge in the

[71]Executive Order 13175 directs federal agencies to have an accountable process to ensure meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications. Exec. Order No. 13175, Consultation and Coordination with Indian Tribal Governments, § 5(a), 65 Fed. Reg. 67249 (Nov. 9, 2000). As an independent regulatory agency, NRC is exempt from the requirements of certain executive orders, including Executive Order 13175. However, Executive Order 13175 encourages independent regulatory agencies like NRC comply with it, and NRC has noted that it has developed agency practices for tribal consultation consistent with the principles articulated in Executive Order 13175. *See* 82 Fed. Reg. 2402, 2403 (Jan. 9, 2017). DOE and NRC have developed tribal consultation policies that govern the agencies' interactions with tribes, including interactions during the siting process. In addition, the siting process may trigger statutory and regulatory requirements for federal agencies to consult with tribes. For example, regulations implementing the National Environmental Policy Act require federal agencies to consult with Indian tribes early when evaluating potential environmental effects of proposed projects or actions. 40 C.F.R. § 1501.2(b)(4)(ii). Additionally, under section 106 of the National Historic Preservation Act and its implementing regulations, federal agencies must consult with Indian tribes when agency undertakings may affect historic properties—including those to which tribes attach religious or cultural significance—prior to the approval of the expenditure of federal funds or issuance of any licenses. Pub. L. No. 89-665, § 106, 80 Stat. 915, 917 (1966) (codified as amended at 54 U.S.C. § 306108); 36 C.F.R. pt. 800.

implementation of Canada's adaptive phased management approach. The Council of Elders and Youth also provides advice on issues that could enhance developing and maintaining good relations with indigenous communities. DOE includes the key role of tribes under its trust relationship with Indian tribes draft principle. Although DOE's draft principle addresses the trust relationship with tribes and does not explicitly call for consultation with tribes, it says the siting process will take into account siting impacts on sacred tribal lands, and other areas and resources of religious or cultural significance.[72]

- **Phased adaptive approach.** Most of the experts we interviewed said a phased adaptive approach is important when siting interim storage facilities or permanent repositories. A phased adaptive approach is a flexible process that is responsive to new information and new technical and social developments. It also allows for the modification of key decisions, if necessary.[73] For example, Canada is using a phased adaptive approach for the long-term management of its commercial spent nuclear fuel with six phases marked by explicit decision points.[74] Canada's phased adaptive approach is consistent with long-term management best practices adopted by other countries with nuclear power programs, such as Finland and Sweden. DOE includes elements of a phased adaptive approach under its stepwise collaborative decision-making draft principle.
- **Voluntary participation.** Most of the experts we interviewed said participation in a consent-based siting process must be voluntary—meaning, the potential host community can opt into the siting process. Further, all of the officials we interviewed from the waste management organizations in Canada, Finland, and Sweden noted that potential host communities must also have the option to withdraw from further

[72]DOE's principle on the trust relationship with tribes also acknowledges the federal government's responsibilities to consult government-to-government with tribes found in Executive Order 13175. In addition, the draft principles also note that the siting process will respect tribal sovereignty and self-determination, lands, assets, resources, and treaty and other federally recognized and reserved rights.

[73]According to NRC officials, NRC's regulations for geologic disposal of spent nuclear fuel have included a phased approach since the early 1980s. Specifically, they said those regulations include requirements for the continued collection and analysis of information to support decision-making in a stepwise approach for the licensing of a geologic repository.

[74]The six phases of Canada's adaptive phased management plan include (1) site selection and regulatory approval, (2) site preparation and construction, (3) operations, (4) extended monitoring, (5) decommissioning and closure, and (6) post-closure monitoring. The end goal is a deep geologic repository in an area with suitable geology and an informed and willing host, as well as the transportation system to move the spent nuclear fuel to the repository.

participation, up to a certain point, without consequences. For example, a policy of the Swedish waste management company, SKB, is to not polarize a potential host community. If the community's mayor consented but there were public protests, SKB would back out. Additionally, SKB guaranteed that potential communities could pull out at any time for any reason during the feasibility studies and site investigations phases. Canada and Finland have similar policies that allow potential host communities to withdraw anytime during the siting process. DOE includes voluntary participation under its voluntariness/right to withdraw draft principle.

- **Informed consent.** Many of the experts we interviewed said informed consent is a critical component of consent-based siting, and a potential host community must know enough to make a decision that protects its interests and results in its expected outcomes. For example, DOE provided money for the Environmental Evaluation Group to conduct independent technical evaluations of the Waste Isolation Pilot Plant near Carlsbad, New Mexico.[75] The Environmental Evaluation Group helped inform the local community about the potential repository. Canada also provided funding to potentially interested communities to seek independent advice and for community learning and engagement. DOE includes informed consent under its informed participation draft principle.
- **Tailored community benefits.** Nearly all of the experts we interviewed said the benefits of hosting interim storage facilities or permanent repositories must go beyond potential employment opportunities. Benefits could include things such as creating research facilities, building academic institutions, and upgrading infrastructure. For example, DOE helped New Mexico obtain federal funding to build a bypass road around Santa Fe, New Mexico, in response to state concerns about nuclear waste being transported through the city to the Waste Isolation Pilot Plant. Sweden took a different approach and offered its two final volunteer communities financial compensation. The community not selected would receive 75 percent of the compensation for participating in the process and the selected community would receive 25 percent of the compensation. The community selected to host the repository would gain additional economic benefits from construction activities, infrastructure investments, permanent jobs to operate the repository, and ancillary development (e.g., research and fabrication facilities). DOE includes

[75]DOE defunded the Environmental Evaluation Group in 2004.

tailored community benefits under its community well-being draft principle.

DOE officials we interviewed said they did not finalize the consent-based siting process after the draft was published in early 2017 because of different priorities in the new administration. However, finalizing the draft could help position DOE to implement a consent-based process for siting, developing, and constructing consolidated interim storage facilities and/or permanent geologic repositories if Congress amends the NWPA to allow for storage and disposal options other than or in addition to the Yucca Mountain repository. In September 2021, DOE officials said the Office of Nuclear Energy was resuming work to implement a consent-based siting process for interim storage, based on the funding and direction from Congress to move forward with such activities. Officials said DOE also plans to use the consent-based process to site one or more repositories, pending congressional direction, and in keeping with an integrated approach to waste management. DOE expects to complete the consent-based process in early 2022, pending the initial request for public input in 2021. According to several experts, a prerequisite to implementing a consent-based approach is to understand public awareness about current spent nuclear fuel management practices and preferences for future management options.

Conclusions

For more than 2 decades, DOE has not fulfilled its contractual responsibility to permanently dispose of commercial spent nuclear fuel. More specifically, for the last 10 years, DOE has not had an active program for managing commercial spent nuclear fuel, and Congress has not funded development of the Yucca Mountain repository or authorized DOE to explore developing a repository at other sites. This long-standing impasse has and will continue to cost taxpayers billions of dollars as more spent fuel accumulates at sites across the country. Numerous working groups, panels, and commissions have reviewed this issue. Many of their recommendations on how to break the impasse over the disposal of commercial spent nuclear fuel mirror those made by experts we interviewed for this report.

There is not consensus among experts on every aspect of spent nuclear fuel management, but certain recommendations have been consistent over time, and most hinge on congressional action. First, nearly all of the experts we interviewed agreed that to help break the impasse, Congress should authorize a new siting process for consolidated interim storage and permanent repository facilities. DOE is not currently authorized to pursue repository options other than Yucca Mountain. This means the

current impasse will continue unless Congress funds the development of a repository at Yucca Mountain—which most experts we interviewed said is not socially or politically viable—or Congress amends the NWPA to authorize a new process for siting, developing, and constructing a repository.

Secondly, to be successful, most of the experts we interviewed agreed that our nation's spent nuclear fuel program must have strong leadership and be insulated from changing political priorities. Currently, there is no mechanism to help ensure long-term continuity and consistency in DOE's leadership and programmatic priorities for spent nuclear fuel management. Establishing an oversight mechanism, such as an independent board, to provide political insulation and continuity of leadership could help ensure established plans for the long-term management of commercial spent nuclear fuel proceed regardless of changes in political priorities.

Finally, to be successful, nearly all of the experts we interviewed agreed that a spent nuclear fuel program must also have access to reliable and sufficient funding. According to many of the experts we interviewed, unreliable funding caused planning inefficiencies in the Yucca Mountain program, which increased programmatic costs and lowered morale among DOE staff. Most of the experts we interviewed said Congress should remove the Nuclear Waste Fund from the annual appropriations process to allow it to function as originally intended, such that its funding is based on life cycle costs of developing a permanent repository and it does not have to compete for funding with other federal programs.

Ultimately, finding a solution for managing and disposing of commercial spent nuclear fuel is a challenge that will require thoughtful and intentional decision-making and planning. Even then, there is no guarantee of success. However, several other countries—including Canada, Finland, and Sweden—have made progress toward developing solutions after facing a similar impasse. These countries' experiences, along with the recommendations from experts, provide useful lessons for a path forward, in particular concerning engaging stakeholders and cultivating public trust. DOE has taken some steps in that direction, including by developing a draft consent-based siting process. Continuing to find ways to build trust and engage the public on spent nuclear fuel management, such as by finalizing the agency's consent-based siting process, could help institutionalize DOE's efforts to engage the public and cultivate trust and prepare DOE to act if Congress authorizes a new siting process.

Matters for Congressional Consideration and Recommendation for Executive Action

We are making the following four matters for congressional consideration:

Congress should consider amending the Nuclear Waste Policy Act to authorize a new consent-based process for siting, developing, and constructing consolidated interim storage and permanent repository facilities for commercial spent nuclear fuel. (Matter for Consideration 1)

Congress should consider creating a mechanism, such as an independent board, to provide political insulation and continuity of leadership for managing the spent nuclear fuel disposal program. (Matter for Consideration 2)

Congress should consider restructuring the Nuclear Waste Fund so funds used to develop, construct, and operate a permanent repository are based on the commercial spent nuclear fuel program's life cycle costs. (Matter for Consideration 3)

Congress should consider directing DOE to develop and implement an integrated waste management strategy, consistent with any amendments to the Nuclear Waste Policy Act, that includes plans for the transportation, interim storage, and permanent disposal of spent nuclear fuel. (Matter for Consideration 4)

We are making the following recommendation to DOE:

The Secretary of Energy should direct the Office of Nuclear Energy to continue its efforts to engage the public and finalize its draft consent-based siting process. (Recommendation 1)

Agency Comments

We provided a draft of this report for review and comment to DOE, the Department of Justice, and NRC.

In its comments, reproduced in appendix IV, DOE stated that it concurred with our recommendation that the Office of Nuclear Energy continue its efforts to engage the public and finalize its draft consent-based siting process. In its comments, reproduced in appendix V, NRC stated it was in general agreement with this report. DOE and NRC also provided technical comments, which we incorporated throughout this report as appropriate. The Department of Justice did not have any comments on this report.

We are sending copies of this report to the appropriate congressional committees and the Secretary of Energy, the Attorney General, and the Chairman of the NRC. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix VI.

Frank Rusco
Director, Natural Resources and Environment

List of Addressees

The Honorable Jack Reed
Chair
The Honorable James M. Inhofe
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Joe Manchin
Chair
Committee on Energy and Natural Resources
United States Senate

The Honorable Tom Carper
Chair
Committee on Environment and Public Works
United States Senate

The Honorable Gary C. Peters
Chair
Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable Diane Feinstein
Chair
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Mike Rogers
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Marcy Kaptur
Chair
Subcommittee on Energy and Water Development
Committee on Appropriations
House of Representatives

Appendix I: Commercial Spent Nuclear Fuel Experts We Interviewed

This appendix provides a list of the experts we interviewed.

Table 3: Commercial Spent Nuclear Fuel Experts We Interviewed

Name	Affiliation
Evaristo J. “Tito” Bonano, Ph.D.	Sandia National Laboratories, Albuquerque, NM, Senior Manager of the Nuclear Energy Fuel Cycle Program
Thomas A. Cotton, Ph.D.	Nuclear Waste Management Consultant
Danielle Endres, Ph.D.	University of Utah, Professor at the Department of Communication
Rodney C. Ewing, Ph.D.	Stanford University, Frank Stanton Professor in Nuclear Security and Co-Director in the Center for International Security and Cooperation in the Freeman Spogli Institute for International Studies and Professor in the Department of Geological Sciences in the School of Earth, Energy and Environmental Science
Charles Forsberg, Ph.D.	Massachusetts Institute of Technology, Department of Nuclear Science and Engineering
Kuhika Gupta, Ph.D.	University of Oklahoma, Research Scientist at the National Institute for Risk and Resilience
Joseph S. Hezir, MSc	Principal and Executive Vice President, Energy Futures Initiative
Tom Isaacs, MSE	Strategic Advisor to Southern California Edison on Nuclear Waste; Lead Advisor to the Blue Ribbon Commission on America’s Nuclear Future
Hank C. Jenkins-Smith, Ph.D.	University of Oklahoma, Co-Director of National Institute for Risk and Resilience and Professor of Public Policy
David M. Klaus, J.D.	Stanford University, Affiliate at the Center of International Security and Cooperation
Bret W. Leslie, Ph.D.	Senior Professional Staff at the U.S. Nuclear Waste Technical Review Board
Edwin S. Lyman, Ph.D.	Director of Nuclear Power Safety, Union of Concerned Scientists
Allison Macfarlane, Ph.D.	University of British Columbia, Director of School of Public Policy and Global Affairs
Daniel Metlay, Ph.D.	George Washington University, Senior Visiting Scholar at the International Institute for Science and Technology Policy University of California Los Angeles, Senior Fellow at the B. John Garrick Institute for the Risk Sciences
Ali Mosleh, Ph.D.	University of California Los Angeles, Professor and Director of B. John Garrick Institute for the Risk Sciences
Nigel Mote, B.Sc. (Hons)	Executive Director of the U.S. Nuclear Waste Technical Review Board
Per F. Peterson, Ph.D.	University of California Berkeley, Professor at the Department of Nuclear Engineering Chief Nuclear Officer, Kairos Power LLC.
Seth P. Tuler, Ph.D.	Worcester Polytechnic Institute, Associate Professor at the Department of Integrative and Global Studies Division, The Global School
David Victor, Ph.D.	University of California San Diego, Professor of Innovation and Public Policy at the School of Global Policy and Strategy Chairman, San Onofre Nuclear Generating Station Community Engagement Panel
Thomas Webler, Ph.D.	Senior Researcher, Social and Environmental Research Institute

Source: GAO. | GAO-21-603

Appendix II: Objectives, Scope, and Methodology

This report examines what actions may be necessary to address the impasse over developing a permanent disposal repository for commercial spent nuclear fuel and effectively managing such fuel. Specifically, this report highlights actions that experts identified as necessary to develop a solution for the management of commercial spent nuclear fuel.

To answer this objective, we reviewed documents and interviewed Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) officials regarding their roles related to managing commercial spent nuclear fuel. We also interviewed Department of Justice officials and reviewed documents related to lawsuits filed by nuclear utilities against DOE for not fulfilling its contractual obligation to dispose of commercial spent nuclear fuel beginning no later than January 31, 1998. We also reviewed documents related to the damages paid by the federal government to nuclear utilities for partial breach of contract.

To determine options for managing commercial spent nuclear fuel and identify experts to interview, we reviewed studies and reports identified from our prior work, preliminary background research,[1] referrals from experts and stakeholders we contacted, and working groups that examined policies for managing the back-end of the nuclear fuel cycle and made strategy recommendations to the federal government.[2] To supplement this research, we conducted a literature review for articles and reports related to managing commercial spent nuclear fuel. To conduct the literature review, we searched Elsevier's Scopus and ProQuest databases for peer-reviewed articles, government reports, hearings and transcripts, industry and trade group publications, conference papers, think tank publications, and working papers published from January 2010 through September 2020. We searched titles, abstracts, and key words for "spent nuclear fuel," "spent nuclear waste," or "Yucca Mountain" in close proximity to terms such as "management," "disposal," "storage," "transportation," "consent-based siting," and "public opinion." In total, we reviewed approximately 150 reports.

[1]Preliminary searches for background material included reports from the Congressional Research Service, Congressional Budget Office, DOE, the national laboratories, and more general internet searches using relevant key words.

[2]Blue Ribbon Commission on America's Nuclear Future*, Report to the Secretary of Energy* (Washington, D.C.: Jan. 26, 2012) and Stanford University and George Washington University, *Reset of America's Nuclear Waste Management: Strategy and Policy* (Oct. 15, 2018).

We also interviewed 20 experts and 25 stakeholders to determine options for managing commercial spent nuclear fuel. To select experts and stakeholders, we compiled an initial list of potential experts and stakeholders using primary authors identified in our literature review, participants in the Blue Ribbon Commission on America's Nuclear Future and Reset of America's Nuclear Waste Management Strategy and Policy working group, recommendations from experts and stakeholders we interviewed, and experts identified in prior GAO engagements.[3] We identified 141 potential experts and 126 potential stakeholders. We separated experts from stakeholders based on their education, work experience, publications, and years of experience. Specifically, we considered someone to be an expert if they had broad-based knowledge on the topic. In contrast, we considered someone to be a stakeholder if they were knowledgeable in the subject matter area but that knowledge was based largely on personal exposure to the topic rather than broader-based knowledge.

From this initial list of 141 experts, we identified experts who authored a publication within the previous 10 years, had expertise in an area relevant to our objective, had knowledge of the history of and policies for managing commercial spent nuclear fuel, and worked in academia, at a nongovernmental research organization, or in the federal government. Relevant areas of expertise included technical aspects of managing commercial spent nuclear fuel (e.g., disposal methods in various rock types, aging management of on-site storage, etc.); public opinion regarding spent nuclear fuel; and cost estimates for storing and disposing of commercial spent nuclear fuel. We then organized the experts into four tiers based on the number of factors (i.e., primary author identified in our literature review, working group participant, recommended by other experts we interviewed, and experts from prior GAO reports) that identified each expert. Tier 1 experts were identified in all four factors; tier 2 experts were identified in three of the four factors; tier 3 experts were identified in two of the four factors; and tier 4 experts were identified in one of the four factors. We generally prioritized tier 1 experts and worked our way down to tier 4 experts, unless individuals had expertise in a relevant area that we wanted to represent. From this list, we identified 20

[3]GAO, *Nuclear Waste Management: Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives,* GAO-10-48 (Washington, D.C.: Nov. 4, 2009) and *Spent Nuclear Fuel Management: Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability,* GAO-15-141 (Washington, D.C.: Oct. 9, 2014).

experts, and all 20 experts agreed to be interviewed (see app. II for the list of experts). We conducted semi-structured interviews with these experts using a pretested instrument[4] and conducted a content analysis of their responses to identify areas of general agreement or themes and categorize the ranges of views. To characterize the experts' views throughout this report, we defined the modifiers "nearly all" to represent 17 to 19 experts, "most" to represent 11 to 16 experts, "many" to represent seven to 10 experts, and "several" to represent three to six experts. These 20 experts are prominent researchers and their research corresponds to a range of major fields of research on the topic, but their views do not represent the views of all experts on the options for managing commercial spent nuclear fuel.

From the initial list of 126 stakeholders, we identified 25 stakeholders who had knowledge of the history of and policies for managing commercial spent nuclear fuel and represented a diverse range of pro- and anti-nuclear views from various organizations. The organizations included nuclear industry trade groups, owners of commercial nuclear power plants, nongovernmental organizations, consultants, tribal and state officials, and officials responsible for commercial spent nuclear fuel management in countries furthest along in siting and developing a geologic repository (i.e., Canada, Finland, and Sweden). All 25 stakeholders we selected agreed to be interviewed. We conducted semi-structured interviews with these stakeholders. The views of these 25 stakeholders cannot be generalized to other stakeholders we did not interview. Rather, these interviews provided us with information and opinions specific to the individuals or groups we selected.

To identify and summarize elements important for an effective siting process and for cultivating public trust in a decision-making process, we reviewed documents and asked relevant questions as part of our semi-structured interviews of the 20 experts and 25 stakeholders. We also interviewed officials responsible for commercial spent nuclear fuel management in Canada, Finland, and Sweden about their experience and lessons learned for engaging the public and cultivating trust. We compared the elements described by experts to those incorporated by DOE in its January 2017 draft consent-based process for siting

[4]We pretested with two experts to ensure the questions were clear and answerable and that we had included all relevant questions.

consolidated interim storage facilities and permanent geologic repositories.[5]

To understand the existing inventory of commercial spent nuclear fuel and estimates of future inventories, we reviewed and analyzed data from Gutherman Technical Services, LLC,[6] DOE, and NRC. We also reviewed and analyzed DOE data on the fees collected from nuclear utilities for the Nuclear Waste Fund, and the interest accrued on those fees, as of September 30, 2020.

To determine the federal government's financial liability and fiscal exposure for commercial spent nuclear fuel, we reviewed DOE's annual agency financial reports and analyzed the dollar amounts in damages that DOE has paid the owners of commercial nuclear reactors for storing spent nuclear fuel at their reactor sites, as of September 30, 2020. We also reviewed and analyzed DOE's estimates of its potential long-term financial liabilities associated with its obligations to pay the owners of commercial nuclear reactors for the costs of storing spent nuclear fuel at reactor sites, as of September 30, 2020.

For any data and estimates we report, we reviewed the methodology to ensure the data and estimates were sufficiently sound and conducted a data reliability assessment on all data sources. Specifically, we assessed the reliability of the spent nuclear fuel inventory and projection estimates by interviewing Brian Gutherman of Gutherman Technical Services, LLC and reviewing his data collection protocols. We assessed the reliability of the Nuclear Waste Fund data by (1) reviewing existing information about the data and the system that produced them and (2) interviewing agency officials knowledgeable about the data. We assessed the reliability of the data in DOE's agency financial reports by relying on the independent public accounting firm KPMG LLP, which audits DOE's financial statements. The audits identified no material weaknesses and no instances of noncompliance with laws and regulations, nor instances in which DOE's financial management stewardship and systems did not comply with governmental financial requirements. We determined the

[5]Department of Energy, *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste* (Jan. 12, 2017).

[6]Gutherman Technical Services, LLC is a consulting firm that provides information on spent nuclear fuel inventories for the Nuclear Energy Institute.

estimates and data to be sufficiently sound and reliable, respectively, for our purposes.

We conducted this performance audit from May 2020 to September 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: Timeline of Key Decisions and Events Related to U.S. Commercial Spent Nuclear Fuel Management

This appendix summarizes some of the key decisions and events related to U.S. commercial spent nuclear fuel management prior to and as a result of the Nuclear Waste Policy Act of 1982.

Table 4: Summary of Key Decisions and Events Related to U.S. Commercial Spent Nuclear Fuel Management

Year	Summary of key decision or event
1934	Enrico Fermi splits the atom and achieves the world's first nuclear fission.
1954	The Atomic Energy Act of 1954 provides direction for the peaceful use of atomic energy, with the understanding that disposal of the radioactive waste would be the responsibility of the federal government, and establishes the Atomic Energy Commission.
1955	The United States begins using nuclear power to generate electricity.
1957	The National Academy of Sciences identifies disposal in a geologic formation as the safest and most secure method of isolating commercial spent nuclear fuel and other types of nuclear waste.
1970	The United States begins search for potential geologic repository sites.
1970	The Atomic Energy Commission selects an abandoned salt mine in Lyons, Kansas, as the first national repository for commercial spent nuclear fuel and defense high-level waste. The Atomic Energy Commission's efforts eventually end in 1972 because of technical uncertainties and public opposition.
1974	The Energy Reorganization Act of 1974 establishes the Nuclear Regulatory Commission (NRC) and provides that it has regulatory authority for, among other things, facilities used primarily for the receipt and storage of high-level waste. The act also repeals the Atomic Energy Act of 1954 and abolishes the Atomic Energy Commission, transferring most of its functions to NRC.
1978	As part of the National Waste Terminal Storage program, the Department of Energy (DOE) begins exploring Yucca Mountain, one of more than 25 sites being examined.
1983	The President signs the Nuclear Waste Policy Act of 1982, which directs DOE to investigate potential sites for a geologic repository. The act authorizes DOE to contract with generators and owners of spent nuclear fuel to take title to (meaning take custody of) and begin disposing of their spent nuclear fuel beginning in January 1998.
1983	DOE initially considers nine sites for the first geologic repository—six in the West and three in the South. In 1984, DOE issues draft environmental assessments on each site.
1984	DOE issues general guidelines (with the concurrence of NRC and after public review and comment) to be used by the Secretary of Energy in considering candidate sites for recommendation.
1986	DOE recommends converting a federally owned site near Oak Ridge, Tennessee, into a consolidated interim storage facility. The governor of Tennessee strongly opposes the project over concerns that the facility would become a "de facto" permanent repository and that availability of spent fuel storage would reduce the pressure for progress on the planned geologic repository.
1986	Of the nine sites considered for the first geologic repository, the Secretary of Energy nominates five sites as suitable for site characterization. Of those five sites, DOE recommended to the President three candidate sites for characterization: 1) Yucca Mountain, Nevada, 2) Deaf Smith County, Texas, and 3) Hanford, Washington. The recommendation document states that DOE assessed the sites using 14 performance measures, including health and safety of the public and workers, environmental and socioeconomic factors, and repository and transportation costs. Yucca Mountain is the top-ranked site—or the site that would cause, in aggregate, the least adverse impact.
1987	The Nuclear Waste Policy Amendments Act of 1987 amends the Nuclear Waste Policy Act of 1982 to direct DOE to investigate only Yucca Mountain for a permanent repository and to phase out all site-specific activities at all candidate sites other than Yucca Mountain. The act authorizes DOE to perform studies to determine if the Yucca Mountain site is suitable for a geologic repository and recommend the site to the President if it meets certain requirements. The amendments also establish an alternative method for finding sites for nuclear waste facilities using negotiated terms and voluntary host communities.

Year	Summary of key decision or event
1990	The President appoints the first Nuclear Waste Negotiator to work with tribal, state, and local governments to find a community willing to host consolidated interim storage facilities. In 1991, DOE makes grants available for feasibility studies on potential consolidated interim storage facilities. The Office of the Waste Negotiator does not sign a siting agreement prior to the office's elimination in 1995.
1996	Private Fuel Storage, consisting of a consortium of nuclear power reactor operators, submits a license to NRC for a centralized interim storage facility in Utah. The NRC approves the license application in 2006, but the facility never begins operations, largely because of state opposition.
1998	DOE is unable to begin taking custody of spent nuclear fuel, as called for by the Nuclear Waste Policy Act, as amended, because of a series of delays due to, among other things, state and local opposition to the construction of a permanent repository in Nevada and technical complexities. However, DOE issues a viability assessment stating that Yucca Mountain is still a viable site.
2002	Per the process outlined in the Nuclear Waste Policy Act of 1982, as amended, DOE recommends the President approve the Yucca Mountain site as a repository for spent nuclear fuel. The President subsequently recommends the site to Congress as suitable for a repository. The Governor of Nevada submits a notice of disapproval to Congress, but Congress votes to approve the site for the development of a permanent, high-level waste repository.
2008	DOE submits a license application to NRC for the construction of a permanent geologic repository at Yucca Mountain for commercial spent nuclear fuel and high-level waste.
2009	The administration announces plans to withdraw the license application for a geologic repository at Yucca Mountain and study other disposal options.
2010	On March 3, 2010, DOE submits a motion to withdraw its license application "with prejudice" and to exclude Yucca Mountain from further consideration as a repository site. The administration does not request money for the Yucca Mountain project in its subsequent annual budget requests to Congress and dissolves the Office of Civilian Radioactive Waste Management.
2011	NRC suspends its licensing efforts on Yucca Mountain.
2012	The Blue Ribbon Commission recommends DOE adopt a consent-based approach to siting consolidated interim storage facilities and geologic repositories.
2013	DOE releases its Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste.
2013	The U.S. Court of Appeals for the D.C. Circuit (D.C. Circuit) rules that NRC must continue evaluating the license application submitted for Yucca Mountain with the money appropriated to NRC for these purposes. In 2015, NRC finishes the safety evaluation report of DOE's Yucca Mountain application. NRC staff find that DOE met applicable regulatory requirements, except for requirements regarding ownership of land and water rights.
2013	The D.C. Circuit rules that as long as the federal government has no viable alternative to Yucca Mountain as a depository for nuclear waste, owners and operators of nuclear power plants should not be charged a fee to cover the cost of that disposal. DOE stops collecting the fee in May2014.
2015	The President determines that a separate repository for high-level radioactive waste from defense-related activities is required, under section 8 of the Nuclear Waste Policy Act of 1982, before proceeding with planning to dispose of defense waste at a non-Yucca Mountain site.
2015	The Secretary of Energy announces that DOE will pursue a consent-based approach to siting facilities for interim storage and disposal.
2017	DOE issues a draft consent-based siting process for consolidated interim storage facilities and permanent geologic repositories to manage commercial spent nuclear fuel and high-level radioactive waste.
2020	The Consolidated Appropriations Act of 2021 appropriates $27.5 million to DOE for nuclear waste disposal activities under the Nuclear Waste Policy Act, as amended, including interim storage activities, of which $7.5 million is to be derived from the Nuclear Waste Fund.

Source: GAO analysis of DOE documents. | GAO-21-603

Appendix IV: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

September 10, 2021

Frank Rusco
Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street N.W.
Washington, DC 20548

Dear Mr. Rusco,

The Department of Energy (DOE or Department) appreciates the opportunity to comment on the Government Accountability Office's (GAO) draft report titled, "*Commercial Spent Nuclear Fuel: Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution* (GAO-21-603)."

The draft report contained one recommendation for the Secretary of Energy. DOE concurs with GAO's recommendation.

The Department is resuming consent-based siting activities and will update the *Draft Consent-Based Siting Process* in early 2022, pending an initial request for public input in 2021.

DOE's more detailed response to the recommendation and technical comments are enclosed.

GAO should direct any questions to Kelly Scott, Office of Nuclear Energy, 202-586-4288.

Sincerely,

Kathryn Huff

Dr. Kathryn Huff
Acting Assistant Secretary
for Nuclear Energy

Enclosure

Enclosure

Management Response
GAO Draft Report: *Commercial Spent Nuclear Fuel: Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution* (GAO-21-603)

Recommendation #1: The Secretary of Energy should direct the Office of Nuclear Energy to continue its efforts to engage the public and finalize its draft consent-based siting process.

DOE Response: Concur

The Office of Nuclear Energy is resuming work to implement a consent-based siting process. This will initially include gathering input from the public on using a consent-based approach to siting federal interim storage facilities. This is based on the funding and direction from Congress to move forward with interim storage activities. The Secretary and the Department also plan to use the consent-based process to site one or more repositories, pending Congressional direction, and in keeping with an integrated approach to waste management.

The Office of Nuclear Energy will use feedback from the public to inform an update to the Department's *Draft Consent-Based Siting Process*; overall strategy for development and operation of an integrated waste management system; and the establishment of a funding opportunity next year. When the Department publishes the updated *Consent-Based Siting Process,* it will not be considered a 'draft.' However, by its nature, a consent-based siting process must be flexible, adaptive, and responsive to community needs. Thus, the phases and steps included in the process are intended to serve as a guide, not a prescriptive set of instructions. Therefore, the Department will not consider it entirely 'final' in nature. This appears consistent with the recommendations of the GAO, as well as the experts interviewed in the report.

Estimated Completion Date: Early 2022, pending initial request for public input in 2021.

Appendix V: Comments from the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 31, 2021

Mr. Frank Rusco, Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Rusco:

Thank you for providing the U.S. Nuclear Regulatory Commission (NRC) with the opportunity to review and comment on the U.S. Government Accountability Office's (GAO) draft report GAO-21-603, "Commercial Spent Nuclear Fuel, Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution." The NRC has reviewed the draft report and is in general agreement with the report. The NRC provides clarifying comments for your consideration in the enclosure.

If you have any questions regarding this response, please contact John Jolicoeur. Mr. Jolicoeur can be reached by telephone at (301) 415-1642 or by email at John.Jolicoeur@nrc.gov.

Sincerely,

Dorman, Dan signing on behalf of Doane, Margaret on 08/31/21

Margaret M. Doane
Executive Director for Operations

Enclosure:
NRC Comments on Draft Report
GAO-21-603

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contact named above, David Marroni (Assistant Director), Marissa Dondoe (Analyst in Charge), Bethany Benitez, Travis Cady, Colson Campbell, Tara Congdon, Robert Dacey, John Delicath, Cindy Gilbert, Holly Halifax, Michael Kendix, Kelsey Kestenbaum, Tom McCabe, Phillip McIntyre, Tricia Moye, Amanda Mullan, Katrina Pekar-Carpenter, Dan C. Royer, and Robert Sanchez made key contributions to this report.

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