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Report to Congressional Addressees

January 2017

NUCLEAR WASTE

Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste

Accessible Version

GAO-17-174

GAO Highlights

Highlights of GAO-17-174, a report to congressional addressees.

January 2017

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Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste

Why GAO Did This Study

DOE had long planned to store defense and commercial nuclear waste in a single repository at Yucca Mountain, Nevada, funded largely from commercial power fees. In 2010, DOE terminated this plan, and then considered developing separate defense and commercial repositories. This approach requires a Presidential finding under the NWPA. In 2015, DOE provided information to the President supporting separate repositories and cited several benefits, including cost efficiencies. On the basis of this information, the President in 2015 reversed a 1985 presidential finding and determined that a separate repository for defense waste was required, setting DOE down the path of developing separate repositories. Taxpayers would likely fund a defense waste repository rather than industry fees. GAO reviewed DOE's efforts to develop a separate defense waste repository. This report assesses (1) the information on benefits DOE provided to the President; (2) the reliability of DOE's cost and schedule estimates; and (3) DOE's efforts to site a defense HLW repository. GAO reviewed DOE documents and interviewed more than 50 experts.

What GAO Recommends

GAO recommends that DOE (1) assess benefits, costs, and schedule estimates, and (2) reassess its decision to conduct site selection activities. DOE agreed on the need for a more thorough assessment, but disagreed on the need to reassess site selection activities, citing benefits of its approach. GAO continues to believe its recommendation is valid, as discussed in the report.

View GAO-17-174. For more information, contact David Trimble at (202) 512-3841, trimbled@gao.gov

What GAO Found

The information that the Department of Energy (DOE) provided to the President about whether a separate defense waste repository was required did not quantify cited benefits, when possible, show how these benefits could be achieved, or show the risks if certain benefits could not be realized as planned. In the information provided to the President, DOE stated that separate repositories for defense high-level waste (HLW) and commercial spent nuclear fuel (SNF) would produce certain benefits. DOE cited benefits in each area required by the Nuclear Waste Policy Act (NWPA)—cost efficiency, public acceptability, regulation, transportation, national security, and health and safety—in concluding that there is a strong basis for a defense HLW repository. Federal guidance states that benefits must be quantified when possible, and that the risk that a benefit may not be realized as planned should be factored into the cost-benefit analysis. DOE officials said their plan was still conceptual and the guidance did not yet apply. Nevertheless, DOE did not show that benefits outweighed costs in recommending to the President that the nation should depart from its longstanding nuclear waste strategy.

DOE's preliminary cost and schedule estimates for the two-repository approach that it provided to the President are not reliable because the estimates do not meet industry best practices. DOE's cost estimates excluded major costs, such as site selection and site characterization costs that could add tens of billions of dollars. Regarding its schedule estimates, DOE did not provide information on how its schedules would be achieved. GAO found that DOE's estimates leave little time for major activities and that DOE's schedule appears optimistic, given its past repository siting experiences. Without reliable estimates that reflect best practices, DOE provided information to the President that supported a decision that could commit the nation to expending undisclosed but significant future resources and to a time frame that appears optimistic.

DOE is planning to develop a process to obtain consent for an eventual repository site; however, DOE faces significant public opposition and certain prerequisites have not yet been established. These prerequisites include updated health and safety regulations, which are necessary for the public to consider as part of a consent-based siting process. Without updated health and safety regulations, which establish radiation exposure limits, the public cannot provide meaningful input into a consent-based siting process and local communities cannot effectively be engaged in hosting potential repository sites. DOE officials acknowledge that health and safety regulations—which were developed in the 1980s—need to be updated and revised for any future defense HLW or mostly commercial SNF repository. Revising such regulations is the responsibility of other federal agencies. Experts and stakeholders told GAO that updated health and safety regulations are a precondition for having discussions with the public and for screening potential sites. An internal project management requirement directs DOE to perform key "preconceptual" planning activities to enhance front-end planning. In proceeding with siting activities without ensuring key prerequisites have been established, DOE runs the risk of increasing public opposition and potentially wasting resources.

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Abbreviations

DOE	Department of Energy
EPA	Environmental Protection Agency
HLW	High-level radioactive waste
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
SNF	Spent nuclear fuel
WIPP	Waste Isolation Pilot Plant

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

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Congressional Addressees:

From 1944 until the 1980s, the United States used nuclear reactors to produce plutonium and other materials for nuclear weapons. These defense-related activities produced about 14,000 metric tons of nuclear waste, consisting of high-level waste (HLW) and spent nuclear fuel (SNF) that are currently stored in facilities in five states and managed by the Department of Energy (DOE).[1] In addition, the nation has nearly 80,000 metric tons of commercial SNF from the nation's fleet of nuclear power reactors—an amount that is expected to increase by more than 2,000 metric tons per year. DOE estimates that the amount of commercial SNF will increase to about 140,000 metric tons over the next several decades. Commercial SNF accounts for about 85 percent of the nation's nuclear waste. For the most part, this material is stored where it was generated, at 80 sites in 35 states. DOE is responsible for disposing of the nation's nuclear waste.

The nation has struggled for decades with the question of how to permanently dispose of nuclear waste. The Nuclear Waste Policy Act of 1982 (NWPA) required the President to determine whether the development of a separate repository—separate from a repository for commercial SNF—was required for the disposal of HLW resulting from atomic energy defense activities. According to DOE, in 1985, President Reagan found that there was no basis to conclude that a defense-only repository was required. According to DOE, the President based his finding on an evaluation prepared by DOE that concluded that cost efficiency was the only difference between developing a separate defense HLW repository and commingling defense and commercial nuclear

[1]Defense HLW is typically measured by volume. To provide a comparable measurement to commercial SNF, DOE told us that its defense nuclear waste consists of about 14,000 metric tons of heavy metal. We simply refer to "metric tons of heavy metal" as "metric tons" for the purposes of this report. Defense nuclear waste consists of mostly liquid waste and irradiated "spent" reactor fuel resulting from the nuclear weapons program. DOE estimates its defense HLW and DOE-managed SNF—including naval SNF and SNF of non-commercial origin—to be 26,829 cubic meters, which assumes treatment of defense HLW and accumulation of SNF through 2035. The U.S. Nuclear Regulatory Commission considers SNF that is accepted for disposal to be HLW.

waste.[2] In 2008, DOE submitted a license application for a commingled repository at Yucca Mountain, Nevada, about 100 miles northwest of Las Vegas.[3] In 2010, however, DOE terminated its efforts to license Yucca Mountain and at that time offered no alternative for managing or disposing of these defense and commercial nuclear wastes.[4] In 2011, we reported that from fiscal year 1983 to DOE's license submittal, DOE spent nearly $15 billion to investigate developing a repository.[5]

In March 2015, President Obama reversed President Reagan's 1985 finding and found that a separate repository for defense HLW was required. The report that DOE provided to the President that served as the basis for his finding was publicly released in March 2015.[6] In this report, DOE's justification for a separate repository cited a number of factors, devoting particular attention to ways in which the circumstances have changed since 1985. For example, because defense HLW is cooler and less radioactive than commercial SNF, DOE reported to the President that a defense-only repository would allow greater flexibility in

[2]The President must evaluate the need for a separate repository for defense-related waste in response to Section 8(b)(1) of the NWPA not later than 2 years after its enactment. President Reagan in 1985 found, based on an evaluation conducted at the time, according to DOE, that there was no basis to conclude that a defense only repository was required. The main reason given at that time for this finding was that by commingling defense and commercial waste in a single repository, DOE expected to achieve cost savings.

[3]While DOE is responsible for the disposal of nuclear waste, the Nuclear Regulatory Commission (NRC) is responsible for licensing the repository where the waste will be stored.

[4]In 2010, at the direction of the President, DOE formed the Blue Ribbon Commission on America's Nuclear Future to review policies for managing nuclear waste. The Commission published its final report in 2012 and, building on the recommendations of the commission, DOE issued a strategy in January 2013 for managing and disposing of HLW and SNF. The strategy called for the centralized interim storage of commercial SNF, followed by permanent disposal with DOE-managed nuclear waste in a commingled repository.

[5]See 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). This figure is in constant fiscal year 2010 dollars. From fiscal year 2009 to fiscal year 2016, DOE reported receiving an additional $1.4 billion in appropriations for nuclear waste management.

[6]*Department of Energy, Report on Separate Disposal of Defense High-Level Radioactive Waste*, (Washington, D.C.: Mar. 2015). DOE also referred to its strategy to temporarily store commercial SNF beginning in 2022 at consolidated interim storage sites while it prepares to permanently dispose DOE-managed nuclear waste and commercial SNF in a repository beginning in 2048.

the selection of geologic media in which a repository could be sited. Specifically, in its report, DOE identified five possible geologic media, including salt, sedimentary, shale, and crystalline, such as granite. Because of this and other factors, DOE reported that it could save time by beginning to dispose of defense HLW first, which could lead to lessons learned that could apply to a subsequent, more complex and mostly commercial SNF repository.[7] Under the current presidential finding, DOE may plan to develop two repositories—one for defense HLW and one for mostly commercial SNF.

According to DOE officials, under current authority, funding for a defense HLW repository would likely come from defense appropriations, whereas DOE's earlier proposed commingled repository—Yucca Mountain—was mostly funded by the Nuclear Waste Fund, a trust fund that was established under the NWPA to pay industry's share of the cost of a nuclear waste repository and that is funded by fees from commercial power generators. Stakeholders from potentially affected states and communities have raised concerns about the potential increased costs to defense appropriations that could result from DOE's plan.

A May 2015 request from the Chairman and Ranking Member of the Senate Armed Services Subcommittee on Strategic Forces asked us to review DOE's efforts to permanently dispose of defense HLW separate from commercial SNF. In addition, a Senate report accompanying the National Defense Authorization Act for Fiscal Year 2017 directed us to annually report on DOE's expenditures and grants related to SNF, repository siting, and development of a consent-based siting program.[8] This report assesses the information provided to the President that served as a basis for the finding that a separate defense HLW repository was required. Specifically, this report assesses (1) what DOE cited as the benefits of a separate defense HLW repository in its recommendation to the President; (2) the reliability of DOE's cost and schedule estimates for its new plan to site, license, and construct a defense HLW repository; and

[7]Defense SNF and HLW of commercial origin are relatively small in volume compared to the volume of commercial SNF, but some of these types of waste share similar characteristic with commercial SNF, such as higher levels of heat and radioactivity than defense HLW. According to DOE, most defense SNF and HLW of commercial origin are likely to be disposed of with commercial SNF.

[8]Senate Report 114-255 to accompany S.2943 National Defense Authorization for 2017 (at 398-399). May 18, 2016.

(3) DOE's efforts to site a defense HLW repository and key challenges, if any, to siting the repository.

For all three objectives, we reviewed DOE documents; interviewed DOE officials from DOE's offices of Nuclear Energy, Environmental Management, and General Counsel; and analyzed information contained in DOE's March 2015 report, which contained the information that DOE provided to the President, according to DOE officials.

To assess the benefits DOE cited in its recommendation to the President about the need for a separate defense HLW repository, we reviewed DOE's March 2015 report and additional planning and cost documents supporting that report. We interviewed 52 experts and stakeholders from 23 key entities that represented a wide range of viewpoints and expertise on nuclear waste management and disposal issues. To ensure balance among the entities, we interviewed representatives from (1) independent groups and academia, (2) community interest groups, (3) industry, (4) state and local governments, and (5) the federal government. We also reviewed federal guidance on planning, budgeting, and acquiring capital assets, including Office of Management and Budget (OMB) guidance on benefit-cost analyses to guide management at key decision points for major activities.

To assess what is known about the projected costs and schedule of DOE's planning efforts to site, license, and construct a defense HLW repository, we reviewed DOE cost and schedule documents and interviewed DOE officials about the estimates they developed for their new plan. We also interviewed staff from Sandia National Laboratories who were familiar with the information presented to the President or who contributed to DOE's March 2015 report and supporting documentation. We also compared DOE's preliminary estimates against the best practices in GAO's *Cost Estimating and Assessment Guide (Cost Guide)*.[9] To assess the reliability of DOE's schedule estimates, we compared DOE's preliminary schedule estimates against GAO's *Schedule Assessment Guide (Schedule Guide)*,[10] which is intended to complement the *Cost Guide* by providing best practices for estimating

[9]*GAO, Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2, 2009).

[10]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

project schedules. To identify potential limitations of DOE's cost and schedule estimates, we interviewed DOE officials and evaluated the assumptions DOE included or excluded in its estimates. We compared these estimates to estimates DOE developed for other programs, such as the Yucca Mountain program.

To examine DOE's efforts to site a defense HLW repository and key challenges, if any, to siting the repository, we interviewed DOE officials and reviewed DOE reports on previous and current efforts to site and develop nuclear waste repositories. We reviewed transcripts of the public meetings DOE held to solicit public input to develop a more collaborative consent-based siting process. We also reviewed previous GAO reports, as well as relevant reports on siting from other entities, such as the Blue Ribbon Commission on America's Nuclear Future and the National Academies of Science. We also interviewed experts and stakeholders on DOE's siting process and siting challenges. Additionally, we reviewed DOE's project management orders on "pre-conceptual" planning activities and other DOE documents that provide direction for front-end planning activities. (See app. I for further information on the scope and methodology of our review.)

We conducted this performance audit from July 2015 to January 2017 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

This section describes the public's longstanding opposition to siting nuclear waste repositories, DOE's efforts to develop a repository under the NWPA and its amendments, and DOE's efforts since terminating the Yucca Mountain repository to develop other strategies to manage and store nuclear waste.

Longstanding Public Opposition to Siting Nuclear Waste Repositories

Public opposition has prevented the federal government from siting nuclear waste repositories for decades. Between the 1950s and 1983, three different federal entities managed disposal responsibilities for nuclear waste.[11] During the 1960s, the Atomic Energy Commission attempted to develop a high-level waste repository near Lyons, Kansas, but abandoned its plans largely due to public opposition. Federal efforts failed for similar reasons for nuclear disposal and storage facilities in Michigan, New Mexico, Utah, and Wyoming. In 1984, an independent panel concluded that these kinds of failures, among other things, contributed to the federal government's lack of credibility with the public in selecting potential sites for nuclear waste storage. The panel described site selection as largely a political process and recommended the creation of a special advisory siting council made up of various key stakeholders for site selection and that, once sited, creation of a separate entity to develop a repository, largely because of the lack of trust in the federal government.[12]

DOE's Efforts to Develop a Repository under the NWPA

DOE is responsible for disposing of the nation's nuclear waste, including defense nuclear waste (see table 1).

[11]The Atomic Energy Commission managed nuclear waste until January 1975, when the Energy Research and Development Administration assumed those responsibilities. DOE replaced the Energy Research and Development Administration in October 1977 and assumed that administration's responsibilities, including management of nuclear waste.

[12]Section 303 of the NWPA directed DOE to undertake a study on alternative approaches to managing the construction and operations of all civilian radioactive waste management facilities. In 1983, the Secretary of Energy created the Advisory Panel on Alternative Means of Financing and Managing Radioactive Waste Facilities. The panel issued its report in 1984. See Advisory Panel on Alternative Means of Financing and Managing Radioactive Waste Facilities, *A Report to the U.S. Secretary of Energy: Managing Nuclear Waste – A Better Idea.* (Washington, D.C.: December 1984).

Table 1: Types of Nuclear Waste in the United States Requiring Disposal by the Department of Energy (DOE)

Type of Nuclear Waste	Subtype of Nuclear Waste	Description	Metric Tons
Commercial spent nuclear fuel (SNF)	Commercial SNF	Fuel removed from commercial power reactors, most of which is thermally very hot and highly radioactive	141,423[a]
DOE-managed nuclear waste	Navy SNF	Fuel removed from nuclear-powered warships, most of which is thermally very hot and highly radioactive	65
	Defense SNF	Fuel from more than 500 different sources, most of which exist in various forms in relatively small quantities and that were produced in support of the nuclear weapons program	2,195
	Defense high-level radioactive waste (HLW)	Waste byproducts from producing plutonium and other materials for the nuclear weapons program and which is generally cooler and less radioactive than SNF	11,655[a]
	Commercial HLW[b]	HLW from a former reprocessing effort for which DOE has disposal responsibility	139[c]
	Commercial SNF[b]	SNF of commercial origin for which DOE has disposal responsibility	240
	Subtotal		**14,294**
Total			**155,717**

Source: DOE. | GAO-17-174

Note: In addition, DOE manages a small inventory of nuclear waste from various nondefense sources, including SNF from its own test and experimental reactors, reactors at U.S. universities, and other government research reactors; commercial reactor fuel acquired by DOE for research and development; and fuel from foreign research reactors.

[a]DOE's projection is based on the amount of commercial SNF for which it expects to assume responsibility when the SNF is removed from currently operating commercial power reactors.

[b]DOE has responsibility for disposing of HLW that accumulated from a now shut-down commercial reprocessing facility in West Valley, New York, and for commercial SNF for which it now has custody, such as that from now shut-down reactors at Fort St. Vrain in Colorado and Three Mile Island in Pennsylvania.

[c]DOE typically measures HLW by volume expressed in cubic meters. However, DOE provided a rough conversion of the volume to metric tons for comparative purposes. The conversion method DOE used was 1 HLW canister is equal to 0.5 metric tons heavy metal, which DOE used in the original Environmental Impact Statement for Yucca Mountain in support of the site recommendation. The defense HLW volume is 20,002 cubic meters, and the HLW of commercial origin volume is 212 cubic meters.

Most DOE-managed waste is defense HLW—a by-product of weapons production and other defense-related activities—and much of it is currently stored in liquid or semiliquid form in large underground tanks. DOE has agreements with the states in which this nuclear waste is stored that govern how the nuclear waste is managed. These agreements can include various dates by which DOE agrees to complete certain activities, such as processing HLW, transferring SNF and HLW to safer storage,

and removing certain nuclear waste from the site. Some of these agreements include penalties if these dates, known as milestones, are not met. DOE has sites in, and agreements with, five states where it stores its waste.[13]

Department of Energy-Managed Nuclear Waste

The Department of Energy (DOE) also manages spent nuclear fuel (SNF) from the Navy through the Naval Nuclear Propulsion Program, which DOE and the Navy jointly operate. The Navy is also a party to agreements with Idaho, where it stores SNF from submarines and aircraft carriers at DOE's site. In addition, DOE manages a small inventory of nuclear waste from various nondefense sources, including SNF from its own test and experimental reactors, reactors at U.S. universities, and other government research reactors; commercial reactor fuel acquired by DOE for research and development; and fuel from foreign research reactors. For example, DOE stores fuel debris from the Three Mile Island accident which occurred in 1979 at a commercial nuclear power plant. It also stores SNF from three commercial power demonstration projects, including from the first commercial-scale high-temperature gas-cooled reactor plant in the United States, at the Fort St. Vrain site in Colorado.

Source: GAO analysis of DOE data. | GAO-17-174

In enacting the NWPA, Congress allowed for multiple repositories for the nation's nuclear waste. For example, to address equity among states, the act required that at least two repositories for commercial SNF be considered so that, according to experts, no single state would bear the long-term disposal obligations for the entire nation's commercial SNF. In addition, the NWPA directed the President to evaluate whether the development of a repository for the disposal of defense HLW activities is required or if defense HLW could be commingled with commercial SNF in a common repository. In particular, section 8(b)(1) of the NWPA directed the President to make the evaluation on the basis of six factors: (1) cost efficiency, (2) health and safety, (3) regulation, (4) transportation, (5) public acceptability, and (6) national security. As noted above, in 1985, President Reagan found there was no basis to conclude that a separate repository for defense HLW was required. President Reagan's finding relied on a DOE evaluation concluding that cost efficiency favored a commingled repository, specifically, commingling defense HLW with commercial SNF was estimated to cost, at that time, about $1.5 billion less than developing two separate repositories.

The NWPA provides for separate funding for defense nuclear waste and commercial SNF. Specifically, the federal government would pay for the management and disposal of defense waste. In practice, these payments have come through defense appropriations, which is also the source of money used to clean up and prepare nuclear waste at DOE-sites for eventual disposal. For the management and disposal of commercial waste, the NWPA created the Nuclear Waste Fund—a trust fund established to collect fees to pay industry's share of a repository. Under the NWPA, DOE is to determine how much industry should contribute to the fund, annually review the established amount, and evaluate whether the collection of the fee will provide sufficient revenue. The rate was originally set at one-tenth of a cent per kilowatt-hour of nuclear-generated electricity.

[13]DOE sites include the Fort St. Vrain site in Colorado, Idaho National Laboratory in Idaho, the West Valley site in New York, the Savannah River site in South Carolina, and the Hanford site in Washington.

Under its NWPA authority, DOE studied six sites in the West and three sites in the South, and by 1986, the agency recommended three candidate sites for further study or "site characterization:" Yucca Mountain in Nevada, Deaf Smith County in Texas, and Hanford in Washington. DOE was also authorized to contract with commercial nuclear reactor operators to take custody of their SNF for disposal at the repository not later than January 1998.[14] In 1987, however, Congress amended the act to direct DOE to focus its efforts only on Yucca Mountain. As a result, DOE went from considering several repositories to only one at Yucca Mountain, which the state of Nevada vigorously opposed. Under the amendment, DOE was to perform studies to determine if the site was suitable for a repository and, if the site met certain requirements, make a site recommendation to the President. After spending nearly $15 billion over about 25 years to investigate and assess a potential repository site,[15] in June 2008, DOE submitted a license application to the Nuclear Regulatory Commission (NRC) seeking authorization to construct a repository at Yucca Mountain that would commingle defense and commercial waste.[16] In 2010, DOE terminated its licensing efforts at Yucca Mountain. Figure 1 shows key events in the nation's nuclear waste management program over the past several decades.

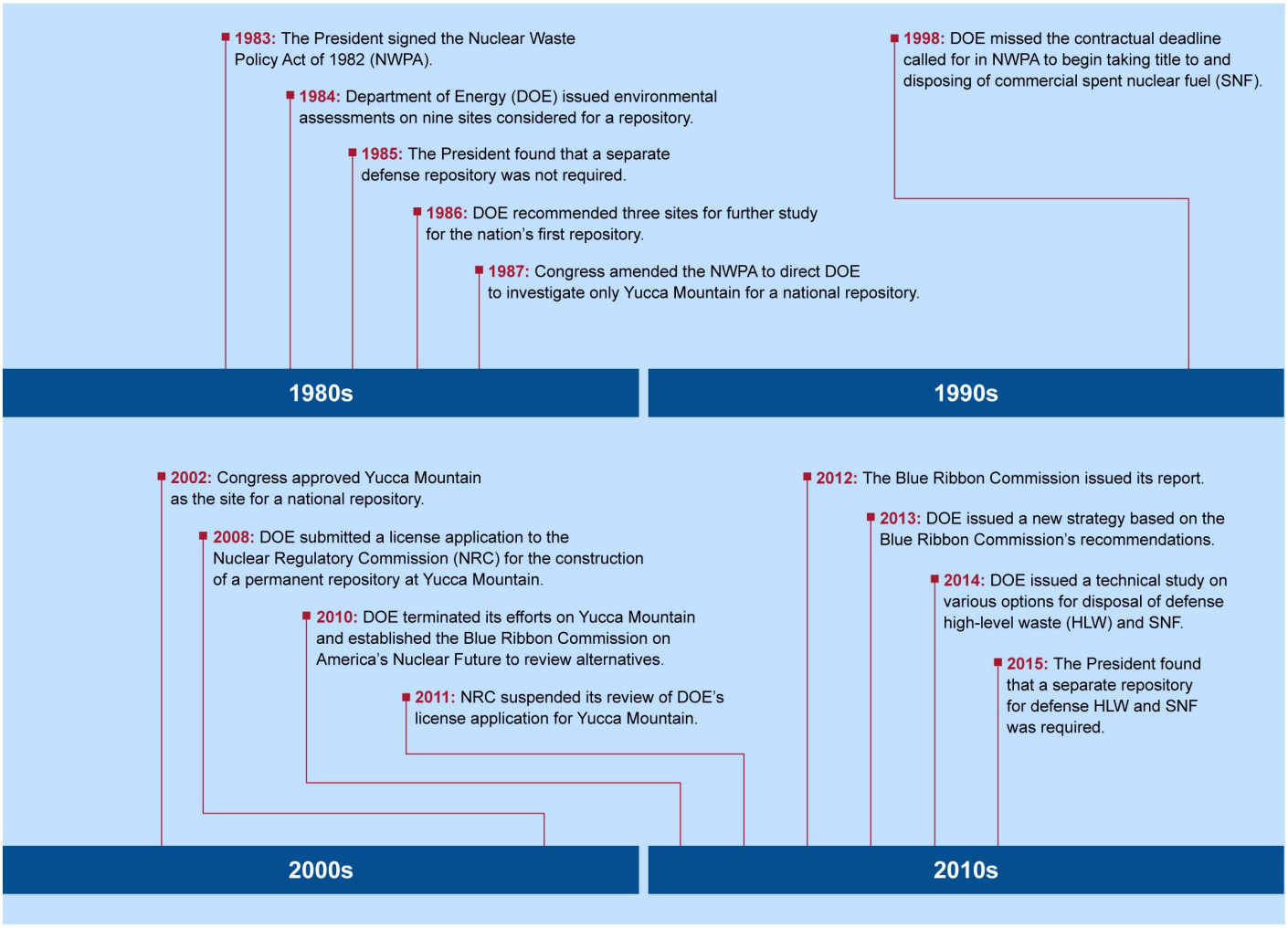
[14]The act generally prohibits the NRC from issuing a commercial license to a nuclear facility that lacks such a contract.

[15]The figure is in constant fiscal year 2010 dollars.

[16]The NRC is responsible for issuing licenses that authorize construction of the repository, as well as operations and closure of a repository.

Figure 1: Timeline of Key Events in Managing Nuclear Waste, 1983, 2015

Interactive Graphic **Instructions: To view more information about each event, place your cursor over the date. For a printable version of the interactive information, see appendix III.**



Source: GAO analysis of DOE and NRC data. | GAO-17-174

Note: Nuclear waste includes DOE-managed nuclear waste and commercial spent nuclear fuel.

The NWPA requires DOE to annually review the amount of the fees collected from industry and evaluate whether these fees will provide sufficient revenues to offset costs. DOE reported in 2013 that the fund's projected balance was adequate to pay for industry's share—about 80 percent—of the costs of a commingled repository. Since DOE terminated its efforts to license the Yucca Mountain repository in 2010, the balance of the Nuclear Waste Fund is about $34 billion. Lawsuits filed in federal appeals court by the Nuclear Energy Institute and the National Association of Regulatory Utility Commissioners resulted in suspension of the fee collection in 2014.[17] In addition, since 1998, owners and generators of commercial SNF have sued DOE primarily in the U.S. Court of Federal Claims for failing to meets its obligations under the contracts that DOE had entered into with them to dispose of commercial SNF. As of the end of fiscal year 2015, the federal government had reimbursed owners and generators about $5.3 billion in connection with such lawsuits.[18] The reimbursements come from the U.S. Department of Treasury's judgment fund.[19] DOE estimates that future federal liability for litigation related to storing spent nuclear fuel will amount to $23.7 billion through 2071.

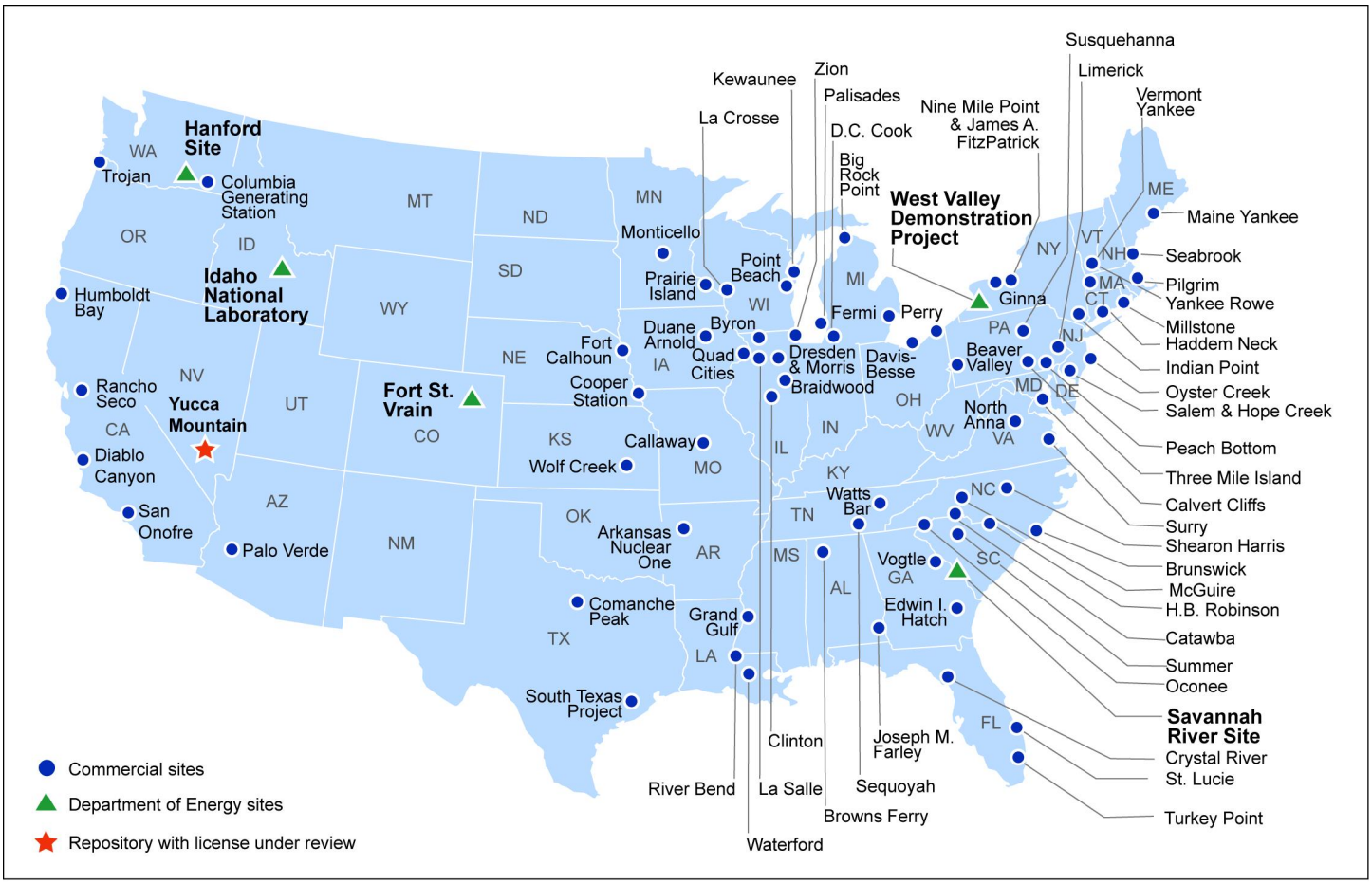
Presently, the nation's inventory of defense nuclear waste and commercial SNF remains stored at 80 sites in 35 states, generally where it was generated (see fig.2).

[17]The Nuclear Energy Institute and the National Association of Regulatory Utility Commissioners sued DOE to suspend collection of the Nuclear Waste Fund arguing that after terminating the licensing efforts for the Yucca Mountain repository, there was no plan on which to evaluate the adequacy of the fee. Ultimately, the U.S. Court of Appeals for the D.C. Circuit ordered DOE to submit a proposal to Congress to set the fee to zero.

[18]In 2014, we also reported that the Department of Justice had spent about $220 million to defend DOE in the lawsuits.

[19]The fund is a permanent, indefinite appropriation for the payment of judgments against federal agencies that are not otherwise provided for by other appropriations.

Figure 2: Storage Sites for Defense-Related and Commercial High-Level Radioactive Waste and Spent Nuclear Fuel



Source: Department of Energy. | GAO-17-174

DOE Efforts to Develop Its New Approach to Managing Nuclear Waste since Terminating the Yucca Mountain Repository

After DOE terminated its efforts to license Yucca Mountain in 2010, it formed the Blue Ribbon Commission on America's Nuclear Future at the direction of the President to, among other things, evaluate alternatives to managing and disposing of the nation's nuclear waste. In 2012, the Blue Ribbon Commission reported that decades of failed efforts to develop a nuclear waste repository have produced frustration and a deep erosion of

trust in the federal government. The commission recommended that the federal government develop a consent-based approach to siting—in which affected units of state, local, or tribal governments willingly enter into legally binding agreements—and create a new organization to implement the waste management program. However, the Blue Ribbon Commission reported that it did not reach consensus on whether defense and commercial nuclear waste should be disposed of separately or in a commingled repository.[20] The Blue Ribbon Commission reported that it did not have the resources to study the merits of a commingled repository versus separate repositories for defense and commercial nuclear waste, but the commission urged the administration to review the implications of re-evaluating the 1985 finding or leaving it in place.

In October 2014, responding to the Blue Ribbon Commission report, DOE issued a report that provided its analysis of disposal options and recommended that DOE pursue separate disposal options for defense HLW and some DOE-managed SNF.[21] In January 2015, DOE submitted a report to the President that included an analysis of the six factors that the NWPA required be reviewed to determine whether to separately store or commingle defense HLW and commercial SNF. On the basis of this information, in March 2015, the President found that the development of a repository for the disposal of defense HLW is required. DOE issued a report available to the public in March 2015 that officials said reflected all the information it provided to the President that served as a basis for the presidential finding.[22]

[20]The commission stated that any investigation of whether the United States should consider reversing the 1985 decision to commingle defense and civilian waste for disposal will require both a re-examination of the factors that were required by section 8 of the NWPA to be evaluated as part of the presidential decision, and an assessment of facts and factors that have changed since the presidential decision. States where DOE-managed waste is stored generally favored this approach, in part because it may mean nuclear waste would be disposed of sooner. On the other hand, the commission reported that a new nuclear waste management organization, if created, could coordinate the management and disposal of the entire inventory of the nation's defense and commercial nuclear waste. The commercial nuclear power industry generally favored the second approach as the most expeditious for disposing of commercial SNF.

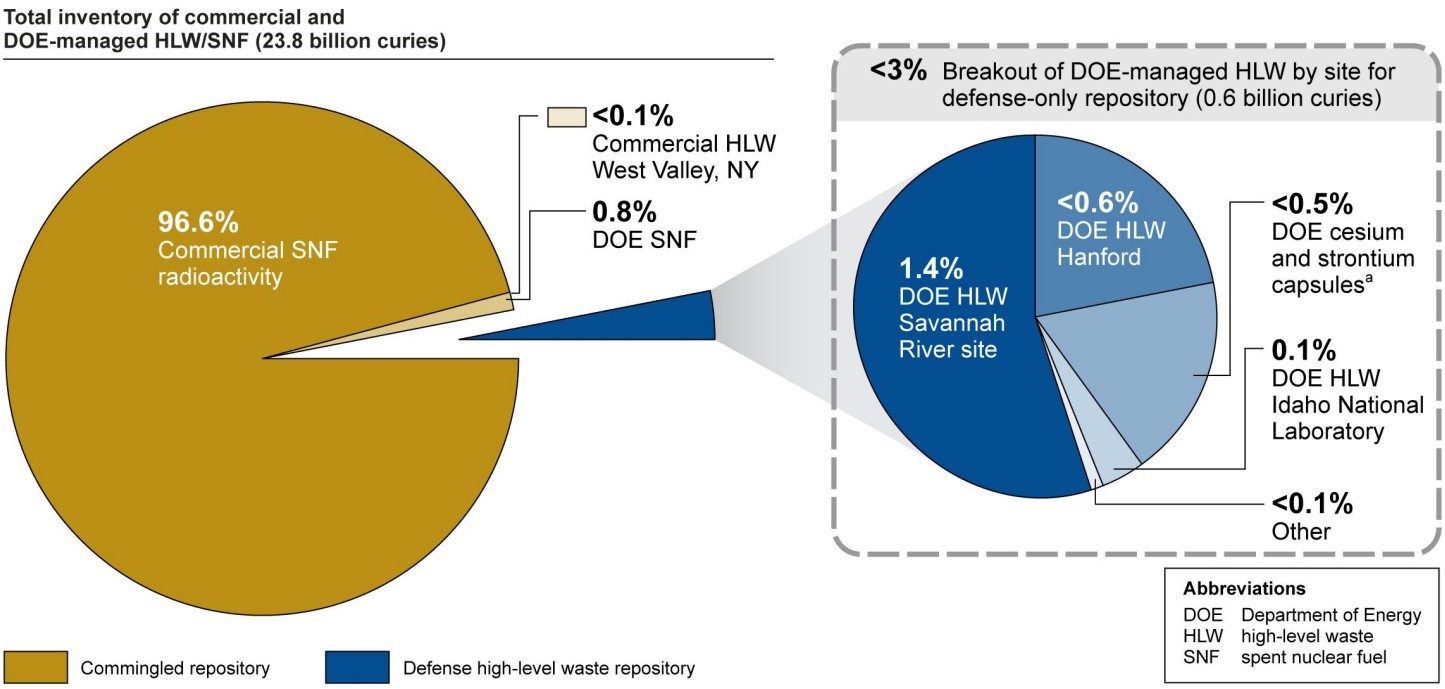
[21]Department of Energy, *Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel*, (Washington, D.C.: October 2014).

[22]Department of Energy, *Report on Separate Disposal of Defense High-Level Radioactive Waste*, (Washington, D.C.: March 2015).

According to the information DOE provided to the President, a defense HLW repository allows for different geologic media and repository designs to be considered because defense HLW—which is typically older than commercial SNF and has already been reprocessed or otherwise treated—is generally cooler and less radioactive than commercial SNF. In addition, DOE noted in the March 2015 report that the defense HLW most likely considered for a separate repository consists of no more than 15 percent of the nation's total nuclear waste by volume, and about 3 percent of the total waste's radioactivity, which is measured in curies (see fig. 3).[23] In the information DOE provided to the President to support his finding, DOE also stated it intends to study the disposal of some defense-related HLW in 5-kilometer-deep boreholes—vertical shafts about 17 inches in diameter—in which HLW capsules with certain highly radioactive elements can be lowered and the shafts sealed.

[23]A curie is a unit of measurement of radioactivity. Under DOE's plan, DOE-managed SNF and HLW of commercial origin have higher thermal and radioactive characteristics more in common with commercial SNF and, therefore, would be disposed of with commercial SNF in a subsequent repository. Most DOE-managed SNF, including the Navy's SNF, would also be disposed of in the subsequent repository with commercial SNF, but according to DOE, some cooler DOE-managed SNF may be disposed of in a defense HLW repository.

Figure 3: Radioactivity of High-Level Waste (HLW) and Spent Nuclear Fuel (SNF) Planned for Separate Defense and Subsequent, Mostly Commercial Repositories (by Curie and Type of Repository)



Sources: GAO analysis of Nuclear Waste Technical Review Board and DOE data. | GAO-17-174

Note: Radioactivity is for the following years: commercial SNF 2011; HLW 2017; DOE SNF 2010; capsules 2006; and other 2000.

[a]According to DOE, cesium and strontium capsules are smaller waste forms eligible for deep borehole disposal.

In Recommending a Separate Defense High-Level Waste Repository, DOE Did Not Quantify Cited Benefits or Show How Certain Benefits Would Be Achieved or the Effect If Not Realized

In the information DOE provided to the President, DOE cited benefits of a separate defense HLW repository but did not quantify the benefits when possible, nor did it provide detailed support demonstrating that the benefits it cited could be achieved or show the risks if certain benefits could not be realized as planned. For example, DOE cited cost efficiency as a benefit, but it did not quantify any cost efficiencies, nor did it estimate

the likelihood that any cost efficiencies could be achieved. Federal guidance on planning, budgeting, and acquiring capital assets states that estimated benefits and costs should be quantified in monetary terms whenever possible and that estimates of costs and benefits should show explicitly the performance and budget changes that result from undertaking the project. The OMB guidance further states that a benefit-cost (or cost-effectiveness) analysis could be used by senior management at key decision points to help decide how best to reduce the performance gap. Furthermore, this guidance states that benefits and cost estimates involve some degree of uncertainty and that the risk that a benefit may not be realized as planned should be factored into the cost-benefit analysis.[24]

DOE's recommendation to the President for a separate defense HLW repository cited benefits in each of the six areas the NWPA required—cost efficiency, public acceptability, regulation, transportation, national security, and health and safety—and concluded that a strong basis exists to find that a defense HLW repository is required. However, DOE did not quantify the benefits, estimate the likelihood that a defense repository could produce these benefits, or show the risks if certain benefits could not be realized as planned. Specifically, we found the following for each of the six benefit areas:

[24]Office of Management and Budget, *Capital Programming Guide, V3.0, Supplement to Office of Management and Budget Circular A-11: Planning, Budgeting, and Acquisition of Capital Assets* (Washington, D.C.: July 2013).

How the Department of Energy Evaluated the Six Factors under the Nuclear Waste Policy Act (NWPA)

The Department of Energy (DOE) reported that in evaluating the six factors required under the NWPA, it included (1) a summary of the 1985 evaluation conclusions; (2) a discussion of post-1985 changes and new information bearing on the cost efficiency factor; and (3) conclusions as to whether each factor supports a finding that a defense high-level radioactive waste repository is required. For the cost efficiency factor, DOE reported that "cost efficiency" is a synonym for "cost effectiveness," a term that, according to DOE, captures both the cost of an action and its benefits.

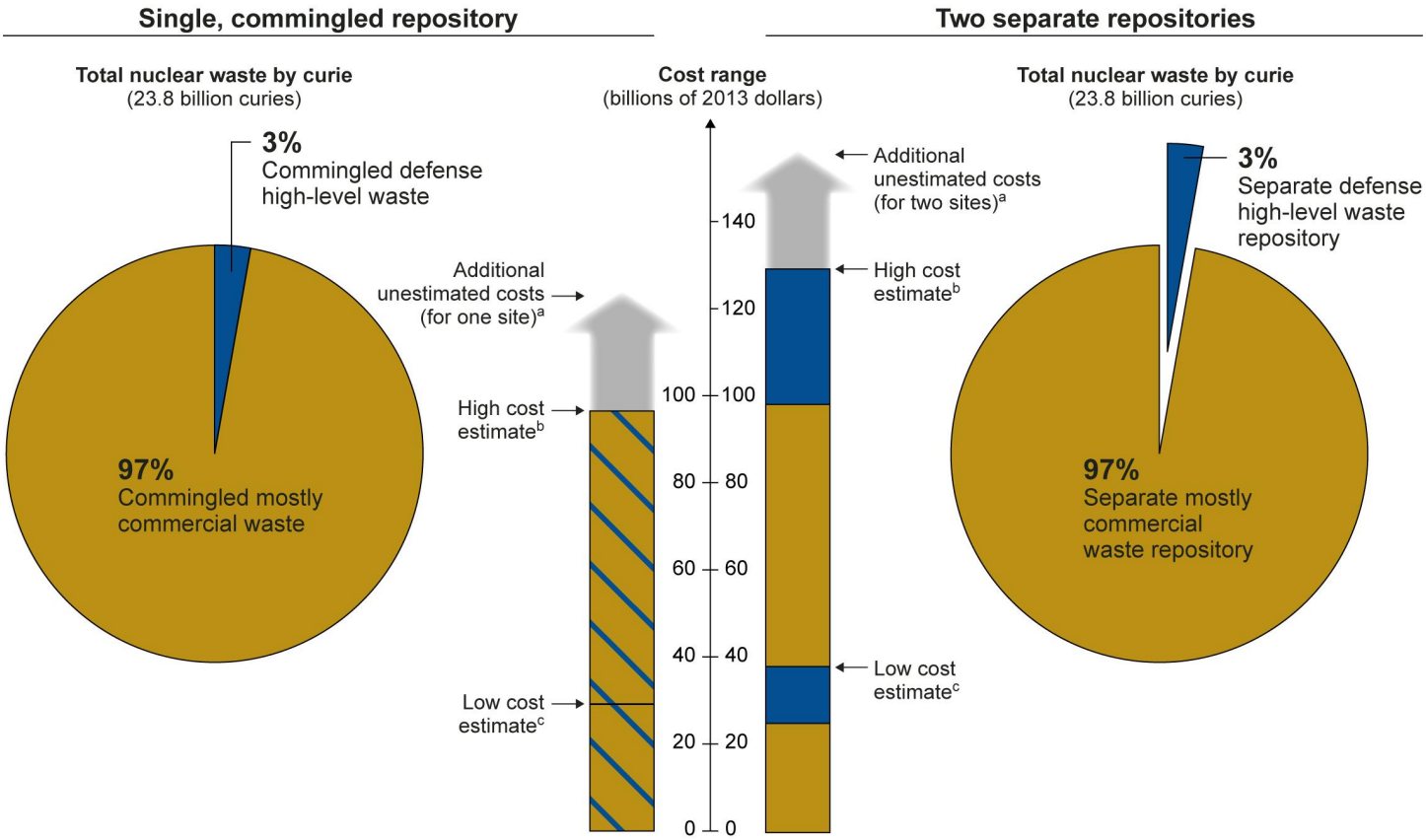
Source: DOE. | GAO-17-174

- **Cost Efficiency**. DOE did not quantify the benefits associated with cost efficiencies of separate repositories that it provided to the President, nor did DOE estimate the likelihood that a defense repository would result in cost efficiencies. DOE reported that the costs of developing two repositories will generally be greater than developing a single repository within each type of geologic media (e.g., salt, shale, or crystalline rock such as granite), but it cited potential cost efficiencies that could result from developing a separate defense HLW repository. For example, a defense HLW repository would allow greater flexibility in choosing different geologic media, since certain geologies and repository designs that might not be considered for commercial SNF may be acceptable for the cooler, less radioactive defense HLW. Figure 4 below compares DOE's cost estimates of a single, commingled repository with the cost estimates of two separate repositories, and the amount of radioactivity associated with each set of costs. DOE also reported that developing a defense HLW repository could result in cost efficiencies for a subsequent, mostly commercial SNF repository by applying lessons learned from the defense HLW repository process. In addition, DOE reported that disposing of defense HLW may allow the department to avoid future storage and treatment requirements for defense HLW, thus reducing future costs.[25] However, we found that DOE did not identify all costs, which we discuss later in this report, nor did it quantify its reported benefits, evaluate the likelihood that these benefits could be achieved, or demonstrate that the benefits outweighed those of a single commingled repository. Some experts agreed that DOE may learn lessons in developing a defense HLW repository, and these lessons could be applied to a subsequent, mostly commercial SNF repository. However, the experts stated that the potential benefits of such lessons—such as improving organizational structure, developing efficiencies in coordinating work, or making better decisions on prioritizing funding—would not result in significant cost savings. Other experts told us that differences between the repository requirements for defense HLW and for

[25]For example, a significant portion of the cost estimates for treating defense HLW is preparing the waste in forms and storage containers that would fit a full range of potential geologic media. However, if the uncertainty of geologic media is removed by siting a repository early, DOE could tailor waste forms and storage containers to a specific type of geology.

commercial SNF would further limit the benefits of lessons learned and likely would not result in cost savings.[26]

Figure 4: Comparison of Costs between Commingled and Separate Repositories, Including Amounts of Radioactivity



Sources: GAO analysis of Nuclear Waste Technical Review Board and Department of Energy data. | GAO-17-174

[26]For example, an independent expert reported that because of differences in temperature and radioactivity between defense HLW and commercial SNF, the designs of a defense HLW repository and a mostly commercial SNF repository would likely be substantially different and lessons from one would not easily apply to the other. The expert added that DOE already has learned significant institutional lessons from working on the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain. DOE did not quantify how additional lessons learned would contribute to cost reductions.

Note: For a single, commingled repository, defense costs may be about 20 percent of the total cost. GAO found that the Department of Energy (DOE) rough-order-of-magnitude cost estimates illustrated by this figure were not reliable because they excluded major costs that will likely add tens of billions of dollars, were minimally documented, lacked transparency, and were not fully credible.

[a]DOE excluded some costs from its estimates, including the costs of selecting repository sites, characterizing those sites, and packaging and transporting waste to the sites. For the two-repository scenario, the cost of site selection and characterization would apply twice—once for each site.

[b]This is the highest estimate (a repository in crystalline rock) in a range of the estimated costs of developing repositories in various types of geologies, each of which has a different cost estimate.

[c]This is the least expensive geological option for developing a repository (salt).

- **Public acceptability.** In the information provided to the President, DOE did not demonstrate that a separate defense HLW repository could result in public acceptability benefits, nor did it assess the potential effect on its analysis if the public acceptability benefits could not be realized. The information DOE provided to the President stated that there is greater likelihood for public acceptance of a defense repository because of the smaller volume and lower heat and radioactivity of the waste destined for it and because the waste derives from national defense activities. In addition, DOE reported to the President that developing a defense HLW repository would improve the public's trust and confidence in DOE's planning and development of repositories, which could help the agency achieve public confidence in a subsequent, mostly commercial repository. DOE also stated that the successful siting of a defense HLW repository could demonstrate to the public that the consent-based siting process DOE plans to develop will be successful for a mostly commercial SNF repository.[27] However, DOE provided to the President little evidence to support its assertion that the public would be more likely to support a defense HLW repository than a commingled repository. Reports spanning several decades have cited public opposition as the key obstacle to siting and building a repository for disposal of nuclear waste.[28] Furthermore, experts and

[27]DOE is in the process of defining and developing its consent-based siting process. According to DOE officials, they are committed to this approach to siting repositories. DOE states that a consent-based approach is built on collaboration with the public, stakeholders, and governments at the local, state, and tribal levels.

[28]For example, in 1982, the congressional Office of Technology Assessment reported that the lack of public confidence in the federal government was the single greatest obstacle to building a repository. The National Research Council of the National Academies reiterated this conclusion in a 2001 report, stating that public opposition is the most significant challenge to siting and commencing operations at a repository. The Blue Ribbon Commission echoed these same concerns in its 2012 report when it stated that public opposition to siting storage or disposal facilities has been the most consistent and most intractable challenge for the U.S. nuclear waste management program.

stakeholders we interviewed generally did not agree with the public acceptability benefits DOE claimed. Specifically, several experts and stakeholders—those representing a community group, an independent entity, and a state government—disagreed with DOE's statement that nuclear waste is more acceptable to the public if it is related to defense activities. Experts from two independent entities said they generally agreed with DOE's statements about public views on a defense HLW repository, but these experts cited as their support DOE's experience with the development of the Waste Isolation Pilot Plant (WIPP) in New Mexico, where the state agreed to host a defense repository for "transuranic" waste after DOE efforts to site a commingled repository for HLW and SNF there failed because of the lack of public acceptance.[29]

Public Acceptance of the Waste Isolation Pilot Plant

The Waste Isolation Pilot Plant (WIPP) provides an example of a success story of a repository for defense nuclear waste, but it took decades to open because of broad and significant opposition from the state and general public. In the end, if not for significant DOE concessions that allowed the state of New Mexico to regulate the waste that DOE would store at WIPP, the repository might not have opened, according to a state government official and DOE contractors. Over time, the public came to support the repository. For example, after two separate accidents at WIPP in February 2014 that led to the suspension of the facility's operations, local officials have publicly supported DOE's efforts to reopen the facility.

Source: GAO analysis of prior work and data from DOE and New Mexico. | GAO-17-174

- **Regulation**. In the information provided to the President, DOE did not demonstrate that a defense HLW repository could be easier or quicker to demonstrate regulatory compliance, as DOE reported, nor did it assess the potential effect on its analysis if the regulatory benefits could not be realized. The information DOE provided to the President stated that regulatory compliance for a defense HLW repository would be simpler to demonstrate and could result in NRC licensing a defense HLW repository sooner than it might a single, commingled repository. DOE acknowledged that for any repository, the regulations—first developed by the Environmental Protection Agency (EPA) and NRC in the early 1980s to assess radiation containment

[29]WIPP is a deep geologic repository. The plant was designed to accept defense-related transuranic waste, not HLW or SNF. Generally, defense-related transuranic waste consists of clothing, tools, rags, residues, debris, soil, and other items contaminated with radioactive elements that are heavier than uranium, such as plutonium, and that were generated as a result of work related to the defense industry.

requirements to protect future populations—need to be updated.[30] In 1992, Congress required more study and directed EPA to create a separate set of regulations specifically for Yucca Mountain. EPA finalized the regulations in 2001, but certain provisions of the regulations were vacated as a result of legal challenges. The agency subsequently issued revised regulations in 2008. These Yucca Mountain-specific regulations do not apply to any other repository. Consequently, to support the licensing of a repository other than Yucca Mountain, EPA would either have to rely on the generally applicable safety standards developed in the 1980s that, according to DOE, need to be updated, or create a new set of regulations. Such regulations would likely be similar to the regulations created for Yucca Mountain, including having a broader array of assessment tools and a longer compliance period, but the regulations could also incorporate new methods of evaluating disposal system performance, according to EPA. DOE also reported that developing a defense HLW repository would provide lessons learned that could facilitate the licensing of a subsequent, mostly commercial SNF repository. However, stakeholders and federal officials told us that the regulatory licensing process would be lengthy for any repository. Moreover, stakeholders from an entity representing community action groups told us that although the reduced volume, temperature, and radioactivity of defense HLW might make it simpler for DOE to meet regulatory requirements, developing the regulatory requirements will still be a time-consuming, complex undertaking. They said developing new regulations would involve public hearings and adjudication

[30]Under NWPA, EPA must develop regulations that provide generally applicable standards to protect the environment from offsite releases from radioactive material in repositories and NRC must develop technical requirements and criteria, consistent with EPA's standards, that it will apply in approving or disapproving applications to construct, receive and possess SNF and HLW in repositories, or close or decommission repositories. EPA and NRC first promulgated these regulations in the early- to mid-1980s. The standards and regulations at that time were based on a "containment" requirement designed to limit the cumulative release of radiation over a period of 10,000 years following the closure of a repository. Since then, however, approaches to determining containment requirements have evolved, resulting in new tools for regulating the disposal of HLW and SNF. For example, EPA's generic safety standards placed greater emphasis on projected health effects to future populations, but new approaches place more emphasis on projected impacts to future individuals. The Energy Policy Act of 1992 directed EPA to issue new regulations specific to Yucca Mountain; EPA applied a broader array of assessment tools and a longer compliance period—one million years—in its revised safety standards for Yucca Mountain. An EPA official stated that it would be reasonable for EPA to consider whether its older generic safety standards should be updated to incorporate these new approaches.

proceedings and, as a result, licensing a defense HLW repository might not necessarily take less time than a commingled repository.[31]

Issuing Regulations for a Nuclear Waste Repository

The Nuclear Waste Policy Act directed the Administrator of the Environmental Protection Agency (EPA) to promulgate generally applicable standards to protect the environment from offsite releases from radioactive materials in repositories. In addition, the act directed the Nuclear Regulatory Commission (NRC) to develop its own regulations to license and regulate repositories consistent with EPA's standards. Although the law allowed NRC to finalize its regulation on licensing before EPA finalized its regulations, if NRC did so, it would have had to revise its regulations, if necessary, to make them consistent with EPA's standards. Developing and finalizing the regulations can be a lengthy process involving multiple stages that require specific time frames for public notification or comment. Certain requirements may affect the rulemaking process, such as the time required for environmental studies or public input. Legislation and lawsuits may also affect the duration of the rulemaking process, such as the Energy Policy Act of 1992, which required EPA to contract with the National Academy of Sciences to conduct a study to find and recommend "reasonable" standards to protect the health and safety of the general public from a repository at Yucca Mountain. EPA would in turn base its own standards on the study's findings and recommendations. According to federal rulemaking officials, these processes may take several years.

Source: GAO analysis of EPA and NRC data. | GAO-17-174

- **Transportation.** DOE did not explain the rationale for the benefits it cited for transportation, nor did DOE estimate the likelihood that the benefits it cited could be achieved or assess the potential effect if the benefits could not be realized. The information DOE provided to the President stated that the development of a defense HLW repository would provide an early opportunity to develop and exercise institutional procedures for transporting nuclear waste. However, we found that lessons learned from such procedures are not likely to provide benefits for the mode of transportation that will be used for commercial SNF. Specifically, representatives of state entities and communities noted that DOE plans to transport commercial SNF by rail, but it plans to transport defense HLW by truck. It is not clear how transporting defense HLW by truck to a defense HLW repository could provide benefits to DOE's plan to transport commercial SNF by rail to a commercial SNF repository.
- **National security**. DOE did not show that the national security benefits it cited could be achieved. DOE reported that if a separate defense HLW repository is developed earlier than a mostly commercial SNF repository, DOE might be able to remove Navy SNF from the Idaho National Laboratory and allow the Navy to avoid potential financial penalties for storing SNF there beyond a certain date. DOE and the Navy may have to pay the state of Idaho $60,000 for each day SNF remains in the state past January 1, 2035, according to agreements with Idaho. We reported in 2011 that the Navy is concerned that if DOE does not remove SNF from Idaho by 2035 then Idaho may bar further Navy shipments of SNF, potentially affecting the Navy's ability to refuel its nuclear fleet after 2035.[32] However, DOE did not show that the national security benefits it cited can be fully achieved. DOE officials reported that it is not likely all of the Navy SNF would be included in the same repository with defense HLW because newer Navy SNF may be too thermally hot and radioactive to be stored in a defense HLW repository.[33] If

[31]WIPP was not licensed under NRC regulations, but was certified as meeting safety standards by EPA.

[32]GAO, *DOE Nuclear Waste: Better Information Needed on Waste Storage at DOE Sites as a Result of Yucca Mountain Shutdown*, GAO-11-230 (Washington, D.C.: Mar. 23, 2011).

[33]Some of the older Navy SNF, which is less radioactive than more recent Navy SNF, may be disposed of in a defense HLW repository, according to DOE.

development of a defense HLW repository delays the development of a subsequent, mostly commercial SNF repository—as some experts and stakeholders say is likely to happen—then the disposal of new Navy SNF would also likely be delayed, and the benefits that DOE said would be achieved under this NWPA factor might not be realized because DOE may not meet the deadlines in its agreement with Idaho.

- **Health and safety**. DOE reported few differences in health and safety benefits between the two repository scenarios because the same level of health and safety protection would be met under any scenario.

As stated earlier, federal guidance provides that estimated benefits and costs should be quantified in monetary terms wherever possible, estimates of costs and benefits should show explicitly the performance and budget changes that result from undertaking the project, and benefit-cost analysis could be used by senior management at key decision points to help decide how best to reduce the performance gap. DOE, however, did not adhere to such guidance. In addition, the guidance states that the risk that a benefit may not be realized as planned should be factored into the cost-benefit analysis. DOE officials stated that the information DOE provided to the President to support the requirement for a separate defense HLW repository addressed the requirements of the NWPA and did not have to adhere to OMB's guidance. They stated that there are no specific requirements under the NWPA for the quality and completeness of information that is provided to support a presidential finding. DOE officials told us they are at the conceptual stages of studying options for a separate defense repository, but they said that when they move from studying repository options to planning for a separate defense HLW repository, they will comply with OMB's guidance. Nevertheless, by DOE not providing the President with complete and, where possible, quantified benefits, the President made a decision that potentially commits the nation to spending tens of billions of dollars and decades of work without the level and type of information federal agencies need to justify key decisions and inform decision makers. Moreover, in choosing to pursue a separate repository for defense HLW without fully assessing the benefits of doing so, DOE appears to have circumvented key front-end planning principles, something DOE has recently emphasized as critically

important in planning for new projects.[34] By using quantified and complete benefits to inform its recommendation to the President, DOE would have greater assurance that the benefits of its approach to storing highly radioactive nuclear waste are greater than the costs.

DOE's Estimates for the Projected Costs and Schedule to Site, License, and Construct a Defense High-Level Waste Repository Are Not Reliable

The preliminary cost and schedule estimates DOE provided to the President for a defense HLW repository are not reliable. Best practices for cost estimating state that, even at the early stages of project development, a reliable cost estimate should encompass all likely costs and be comprehensive, well-documented, accurate, and credible to the extent possible in order to inform decision making. In addition, best practices for schedule estimating state that at early stages of project development, reliable schedule estimates should be connected to the work planned and represent an integrated series of activities. According to DOE officials, they did not develop reliable estimates to reflect all likely costs and schedule activities because their plan was still at the conceptual stage, and DOE officials did not have enough information to generate cost and schedule estimates that met best practices; however, industry best practices documented by GAO state that it is possible to generate reliable estimates of cost and schedule even when information is limited.

[34]For example, in August 2013, the Secretary of Energy created the Contract and Project Management Working Group to study DOE project management and recommend improvements. In November 2014, the Working Group found that insufficient front-end planning has consistently contributed to DOE projects not finishing on budget or on schedule. In reviewing previous and ongoing DOE major projects, the Working Group found that more rigorous front-end planning and analyses would likely have resulted in the selection of different capital construction projects for some of the major projects.

DOE's Cost Estimates Are Not Reliable

In the information DOE provided to the President, DOE prepared "rough order of magnitude" cost estimates for the defense HLW repository, which included cost ranges to design, construct, operate, and close the repository.[35] DOE also included cost estimates for a second, mostly commercial SNF repository. The cost ranges corresponded to different geologies where the repository might be located and within each geology. DOE set each high and low cost range by assuming a predetermined amount of contingency, instead of by assessing the risk that costs may vary. According to DOE documents, each type of geology presents advantages and disadvantages for construction, long-term waste storage, and other technical characteristics. For example, DOE found that crystalline rock, which includes hard rock such as granite, would be more costly because the repository would need additional engineered barriers to contain the radioactive waste. In contrast, DOE told us that bedded salt would be less costly because, among other things, it isolates the waste sufficiently from the environment such that waste packaging requirements are reduced. DOE also provided cost ranges for additional geologies and designs; for example, DOE provided estimated cost ranges for a repository in sedimentary rock in which the nuclear waste would be allowed to decay and then sealed with earth (known as "backfilled") after 100 years. DOE's cost estimates are shown in table 2.

Table 2: The Department of Energy's Rough-Order-of-Magnitude Cost Estimates Provided to the President for Developing Two Repositories, Including a Separate Repository for Defense High-Level Waste (in billions, 2013 dollars)

Geology of repository	Costs of defense high-level waste repository[a]		Costs of second, mostly commercial SNF repository[b]	
	Low	High	Low	High
Crystalline (such as granite)	34	44	64	85
Clay/Shale	33	44	63	84

[35]GAO's Cost Guide states that the rough-order-of-magnitude estimate is typically developed to support "what-if" analyses and is helpful in examining differences in high-level alternatives to identify which are most feasible. However, the *Cost Guide* states that, because this estimate is developed from limited data and in a short time, it should never be considered a budget-quality cost estimate. GAO's Cost Guide is used to evaluate the reliability of rough-order-of-magnitude estimates. The nature of a rough-order-of-magnitude estimate means that it is not as robust as a detailed, budget-quality, life-cycle estimate and its results should not be considered or used with the same level of confidence. Because of this, we performed a high-level analysis of DOE's preliminary cost estimates and methodology by summarizing the best practices sub-criteria for reporting purposes.

Sedimentary Backfilled	18	24	34	45
Shale (not backfilled)	14	19	27	36
Bedded Salt	13	18	25	34

Source: GAO analysis of Department of Energy data. | GAO-17-174

Note: GAO found that these Department of Energy (DOE) rough-order-of-magnitude cost estimates were not reliable because they excluded major costs that will likely add tens of billions of dollars, were minimally documented, lacked transparency, and were not fully credible. Some figures are corrected from DOE's March 2015 report to the President, because they originally contained a few minor rounding errors. DOE corrected these errors when it provided us with the calculations for its estimates.

[a]According to DOE officials, if past practice continues, the entire cost of a defense HLW repository would likely be paid with defense appropriations.

[b]According to DOE officials and documents, most of the costs of a second, mostly commercial SNF repository would be paid from the Nuclear Waste Fund, but because a small portion of the waste is of defense origin, some percentage of the repository costs would also likely be paid with defense appropriations.

We assessed DOE's cost estimates against the characteristics of high-quality, reliable cost estimates as established by industry best practices, which are documented in our Cost Guide. These best practices apply to cost estimates throughout a project's life cycle, including early, rough-order-of-magnitude estimates developed at or before project initiation. According to cost estimating best practices, four characteristics make up reliable cost estimates—they are comprehensive, well-documented, accurate, and credible. Reliable cost estimates are crucial tools for decision makers, according to industry best practices. Cost estimates are considered reliable if each of the four characteristics is substantially or fully met. If any of the characteristics are not met, minimally met, or partially met, then the estimates cannot be considered reliable. OMB guidance also notes the importance of reliable cost estimates at the early stages, stating that early emphasis of cost estimating during the planning phase is critical to successful life cycle management—in short, determining whether benefits outweigh costs.

We found that DOE's cost estimates were not reliable because they excluded major costs that will likely add tens of billions of dollars, were minimally documented, lacked transparency, and were not fully credible. Table 3 summarizes our assessment of DOE's cost estimates.

Table 3: GAO Assessment of Department of Energy (DOE) Cost Estimates Provided to the President for Two Repositories, Including a Separate Repository for Defense High-Level Waste

Characteristics of reliable cost estimates		GAO assessment
Comprehensive	A comprehensive cost estimate has enough detail to ensure that cost elements are neither omitted nor double counted.	Partially met. DOE excluded significant costs, such as site selection, site characterization, and waste packaging and transportation. DOE provided detailed estimates of some activity costs.
Well-documented	A well-documented cost estimate allows for the data it contains to be traced to source documents.	Minimally met. DOE had to re-create calculations for GAO because DOE did not include all source data in its documentation.
Accurate	An accurate cost estimate is based on an assessment of most likely costs; contains few, if any, mathematical errors; and has been adjusted properly for inflation.	Partially met. DOE's cost estimates lacked confidence levels, so we could not determine the degree of precision applied to the estimates. The estimate contained a few minor mathematical errors primarily related to rounding.
Credible	A credible cost estimate discusses any limitations because of uncertainty or bias surrounding data or assumptions.	Minimally met. DOE's cost estimates did not include an independent cost analysis, and major cost elements were not verified. DOE documents indicate that the reports were peer-reviewed.

Source: GAO analysis of Department of Energy data. | GAO-17-174

We shared with DOE officials the results of our assessment of DOE's cost estimates that DOE provided to the President. A complete analysis of DOE's cost estimates and DOE's response is found in Appendix II. We summarize our assessment and DOE's responses below.

- **Comprehensive.** We found that DOE's estimate did not fully conform to best practices for reliable cost estimates because it excluded major activities that could cost tens of billions of dollars. According to industry best practices, comprehensive cost estimates should be structured in sufficient detail to ensure that cost elements are neither omitted nor double counted. Where information is limited and judgments must be made, the cost estimates should document all ground rules and assumptions that may influence the cost estimates' results. DOE's cost estimate, however, did not estimate the cost of major activities that would be required to develop its two proposed nuclear waste repositories. For example, DOE's estimates did not include the following costs:
- **Site selection.** This would likely require scientific investigation of several candidate locations, along with a lengthy consent-based siting process. DOE's past experience with site selection indicates that site selection could cost billions of dollars. For example, a 2013 DOE

study estimated that site selection costs for a new repository will exceed $3 billion, based on the historical costs incurred by Yucca Mountain. Notably, because DOE now must site two repositories, the cost of selecting a site would apply twice—once for each of the two separate sites.

- **Site characterization.** Site characterization cost about $2.6 billion for WIPP and about $8.5 billion for Yucca Mountain, according to DOE officials.[36] As with site selection, the costs of site characterization for two repositories would apply twice—once for each of the two separate sites.
- **Waste transportation.** DOE excluded the cost of packaging, shipping, and transporting the nuclear waste. In 2013, DOE had separately estimated these costs to be a total of about $20 billion.[37]

In response to our analysis, DOE officials stated that DOE was not required to provide the President with comprehensive estimates of life-cycle costs that met industry best practices, in part because of the early stage of their plan's development and because potential sites had not been selected, which could change repository costs.[38] We recognize that at the early phases of a project, cost estimates are preliminary and may not include the details needed in the later stages of project development. However, industry best practices, as

[36]Site characterization is defined as research activities with respect to a test and evaluation facility at a candidate site and activities undertaken to establish the geologic condition and parameters of a candidate site, including borings, excavations of exploratory shafts, and site testing needed to evaluate the suitability of a candidate site for the location of a repository. Site characterization follows preliminary geophysical testing to screen potential sites during site selection.

[37]Department of Energy, *Nuclear Waste Fund Fee Adequacy Assessment Report* (Washington, D.C.: Jan. 16, 2013). The costs for packaging, shipping, and transporting the nuclear waste include costs for canisters, casks, and transportation costs. The NWPA requires DOE to annually review the Nuclear Waste Fund fee to evaluate whether its collection will provide sufficient revenues to offset the commercial utilities' share of the total life cycle costs of the federal government's disposal activities. 42 U.S.C. § 10222. In technical comments responding to our draft report, DOE stated that this cost estimate included costs for civilian waste, but DOE did not provide transportation cost estimates for a defense-only repository.

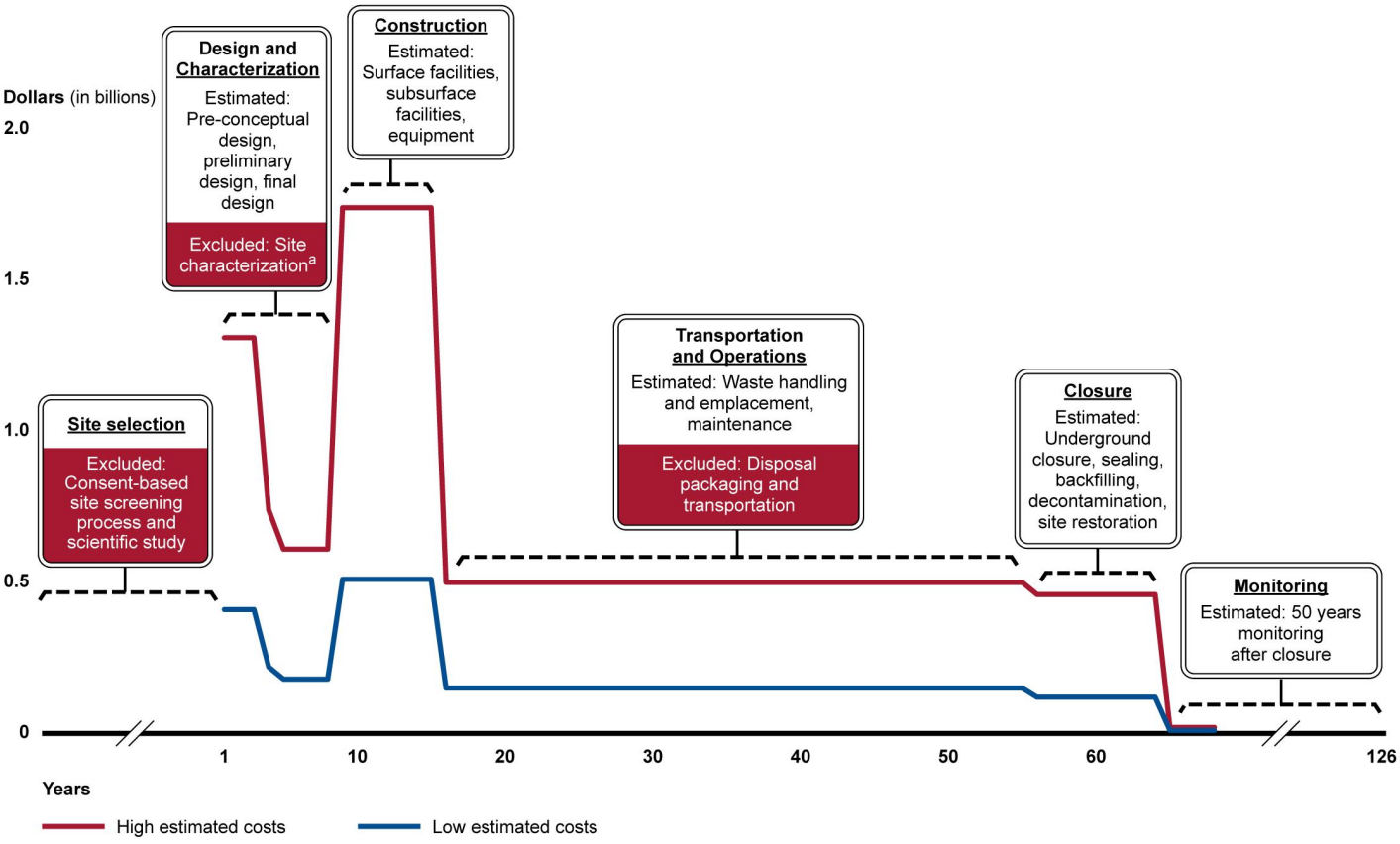
[38]Specifically, DOE officials stated that more complete cost estimates were not required because DOE project management requirements did not apply at this stage of early development. See Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B, Change 2 (Washington, D.C.: May 12, 2016). See also Appendix II for more information about GAO's analysis and DOE's response.

documented in our Cost Guide, state that a full accounting of all life-cycle costs is helpful in examining alternatives to identify which are most feasible.

Figure 5 shows the cost estimates DOE provided to the President, reflecting DOE's highest estimated costs and lowest estimated costs over time for developing a defense HLW repository. These costs would be funded with defense appropriations. As shown in figure 5, the costs are expected to be high during construction, followed by reduced but consistent costs during transportation and operations, then a period of increased costs for closure, followed by substantially reduced costs for monitoring. The figure also shows the activities for which DOE excluded costs; the amounts required are uncertain but will likely add billions of dollars to the estimates. The information DOE provided to the President did not discuss the potential budgetary impact of a defense repository funding needs—up to $1.7 billion per year over several years—on other defense programs managed by DOE.[39]

[39]DOE is responsible for the management and security of DOE's nuclear weapons, nuclear nonproliferation, and naval reactor programs. In its Stockpile Stewardship and Management Plan, DOE describes its long-term modernization plans and budget estimates and provides information on modernization and operations plans and budget estimates over the next 25 years. The plan is a more detailed planning document on which DOE bases its portion of the fiscal year 2016 joint report with the Department of Defense. See GAO, *Nuclear Weapons Sustainment: Improvements Made to Budget Estimates Report, but Opportunities Remain to Further Enhance Transparency*, GAO-16-23 (Washington, D.C.: Dec. 10, 2015).

Figure 5: Department of Energy's (DOE) High- and Low-Range Cost Estimates for Developing a Defense High-Level Waste Repository, Along with Activities for which DOE Did Not Estimate Costs (in billions, 2013 dollars)



Source: GAO Analysis of Department of Energy data. | GAO-17-174

Notes: The figure illustrates identical schedules for both the lowest cost estimates and the highest cost estimates. DOE officials told us that by increasing the funding at a more complex geologic site, they could keep to the same schedule as at a less complex geologic site. Estimated costs for DOE's proposed borehole research and development, and possible implementation, are not reflected in the figure because DOE did not provide cost or schedule estimates for these items. Also, it is not certain what effect borehole disposal may have on the costs and schedule of a defense HLW repository because borehole disposal is limited to certain types of small packages and does not eliminate the need for a geologic repository.

Additionally, GAO found that the DOE rough-order-of-magnitude cost estimates illustrated by this figure were not reliable because they excluded major costs that will likely add tens of billions of dollars, were minimally documented, lacked transparency, and were not fully credible.

[a]DOE officials told us that they did not estimate the duration of the "site characterization" activity but stated that it would, to some degree, overlap with the design activity. As a result, it is possible that site characterization could begin earlier than the first year shown in the chart.

- **Well-Documented.** We found that DOE's cost estimate minimally met the characteristic of a well-documented estimate. According to industry best practices, a well-documented cost estimate allows tracing of the data it contains to source documents and has thorough documentation, including evidence of management review and approval. DOE officials told us that from 2012 through 2015, DOE produced hundreds of pages of engineering reports analyzing how different combinations of nuclear waste might be disposed within different geologies, including rough engineering plans and preliminary cost and schedule estimates. Officials told us that DOE used these engineering reports to support the cost estimates it presented in its March 2015 report to the President. However, when we requested DOE's original calculations for its final cost estimates, DOE officials had to re-create these calculations. In addition, DOE's supporting documentation for its cost estimates was not transparent. Specifically, DOE did not make many of its supporting documents available to the public, such as posting them on the agency's website. As a result, members of the public and the scientific community were not able to evaluate the basis of DOE's cost estimates.

  In response to our analysis, DOE officials agreed that DOE's overall methodology was not clearly documented, but they stated that they provided us with documents that contained all data and assumptions DOE used to develop the cost estimates. However, we found that many of the cost figures that DOE provided to the President could not be traced to the support documents that DOE provided without acquiring additional documentation and consulting with DOE officials.

- **Accurate.** We found that DOE's cost estimates partially met the characteristics of an accurate estimate. To be considered accurate, according to industry best practices, cost estimates should provide results that are: unbiased and not overly conservative or optimistic; based on an assessment of most likely costs; adjusted properly for inflation; reflect risk and uncertainty; and contain few, if any, mistakes. DOE's cost estimates conformed to industry best practices in that DOE took inflation into account and the figures appeared to contain only minor mathematical errors. In addition, there was little variance between planned and actual costs, since DOE had not yet spent money to execute its plan. However, DOE's cost estimates did not fully meet this criterion because DOE did not calculate its cost estimate ranges based on industry best practices using statistical calculations called for by industry best practices and as described in

DOE's cost estimation guidance.[40] If decision-makers are to understand the risk of cost overruns and make wise decisions, they must understand the level of confidence DOE had in its cost estimates. In contrast, DOE did not set the high and low ranges of its cost estimates by assessing risk, but by assuming a predetermined amount of contingency—an amount of funds that DOE officials added for dealing with potential unplanned costs.

In response to our analysis, DOE officials stated that at this stage, DOE does not have the details needed for the kind of statistical analysis called for by best practices.[41] However, best practices describe how a statistical analysis can be undertaken with limited information and communicated to decision makers. Presently, it is not possible to determine whether DOE's estimates are at risk of being either overly conservative or overly optimistic, and decision makers cannot know how much confidence they should have in DOE's estimates.

- **Credible.** We found that DOE's estimates minimally met the "credible" characteristic, which reflects the extent to which a cost estimate can be trusted, according to GAO's Cost Guide. To be credible, a cost estimate should be checked for its level of uncertainty using an independent cost estimate to identify and correct potential bias and a sensitivity analysis to determine how much an estimate could vary as assumptions or conditions change. DOE did check some components of its estimates. For example, DOE documents indicate that a peer review, which served as an independent check, was conducted on some of DOE's source documents. However, DOE has not yet undertaken an independent cost estimate or a sensitivity analysis showing how the assumptions DOE used may affect the results of its cost estimates, as called for by industry best practices.

  In response to our analysis, DOE officials stated that they believed the development of their estimates were well-documented. DOE officials said that departmental orders do not require the same level of

[40]See DOE *Cost Estimating Guide*, DOE Order 413.3-21 (Washington, D.C.: May 9, 2011), Chapter 6.4.5.

[41]DOE officials told us that they applied an amount of potential contingency needed for the type of preliminary cost estimates they developed following DOE cost estimation guidance relevant to the early stage of DOE's planning efforts. DOE did not, however, conduct a quantitative risk assessment that would determine a confidence level and a range, per best practices documented in our *Cost Guide* and DOE guidance. For a more detailed comparison of DOE's cost estimates with best practices, see Appendix II of this report.

analysis at this early stage that is required at later stages. We note, however, that even rough-order-of-magnitude estimates benefit from identification of potential sensitivities, and including them is an industry best practice.[42] Without analyzing how DOE's assumptions or conditions may affect the results of its cost estimates, DOE's estimates cannot be viewed as credible.

According to OMB guidance, poor cost estimates can undermine a program or create an unexecutable plan. DOE excluded certain costs—even in cases where reasonable comparisons were available—without indicating their eventual effect on the lifecycle cost. In doing so, the information DOE provided to the President to support the decision to develop a separate repository for defense HLW omitted billions of dollars in expected costs and was not fully comprehensive, well-documented, accurate, or credible. In this case, because not all costs were included—along with confidence levels to reflect the risks that could adversely affect the program—DOE officials do not know whether a benefit-cost analysis would have shown that a single, commingled repository would be more cost efficient.

DOE Did Not Develop Reliable Schedule Estimates

In the information DOE provided to the President, DOE estimated that both repositories could be ready to receive nuclear waste by 2048. We assessed DOE's schedule estimate against the characteristics of high-quality, reliable schedule estimates as established by industry best practices, which are documented in our *Schedule Assessment Guide.*[43] We found that DOE's estimates for developing and operating both repositories were not well-constructed and that beginning operations at two repositories by 2048 appears optimistic.

As part of its justification to develop a defense HLW repository, DOE reported to the President that a defense HLW repository, if developed

[42]DOE, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B, Change 2 (Washington, D.C.: May 12, 2016).

[43]GAO-16-89G. This guide states that, as a model of time, an integrated and reliable schedule can show when major events are expected as well as the completion dates for all activities leading up to them, which can help determine if the program's parameters are realistic and achievable.

first, could benefit the siting and development of a subsequent, mostly commercial repository. DOE did not report any specific time frames for when it might begin operations at a defense HLW repository, but it did report that its goal was to begin operations at a mostly commercial repository by 2048, and that a separate defense HLW repository could be available before then. The key steps required to begin operations at a repository include selecting the site, assessing or characterizing the geologic characteristics of the site, and, if the geology meets requirements, designing and constructing the repository and obtaining a license to receive and possess nuclear material.[44] DOE provided us with its preliminary schedule estimates for developing both a defense HLW repository and a subsequent mostly commercial repository. DOE's preliminary estimates showed that DOE could finish emplacing waste in both repositories about 47 years after site construction. DOE officials told us that these estimates were preliminary and rough order of magnitude (see table 4).

Table 4: Details of Department of Energy's (DOE) Schedule Estimates for Simultaneously Developing Separate Repositories

Activity element	Time frame
Site development, design, and construction	
Site selection	not estimated
Site characterization[a]	not estimated
Total design and construction	15 to 25 years
Operations	
Waste acceptance and emplacement operations	47 years
Closure	
Ventilation (for clay/shale and sedimentary geologies only)[b]	100 years
Closure	9 to 12 years
Post-closure monitoring	50 to 75 years

Source: Department of Energy data. | GAO-17-174

[a]DOE officials told us that they did not estimate the time required for site characterization but that it would, to some degree, overlap with design activity.

[b]According to DOE officials, this activity would not be needed for the separate defense repository.

[44]Specifically, under NRC regulations, NRC may authorize construction of a repository if it determines there is reasonable assurance that certain safety and security standards are met and that environmental values are protected, which includes weighing environmental, economic, technological, and other benefits against environmental costs. NRC may issue a license to receive and possess nuclear material once NRC determines that construction has been substantially completed and the repository has met applicable requirements as part of the licensing process.

DOE's goal to open a commercial SNF repository by 2048 and a defense HLW repository even sooner appears optimistic. According to DOE's estimates, design and construction will require 15 to 25 years; therefore, these activities would have to begin between 2023 and 2033 for DOE to meet its 2048 goal. As a result, DOE would need to complete site selection and characterization activities in 6 to 16 years (i.e., between 2022 and 2032). DOE would have even less time to complete the site selection and characterization activities required to open a separate defense HLW repository before 2048. DOE did not provide a schedule estimate for completing site selection and characterization activities for either repository, nor did DOE explain how these activities could be achieved in this timeframe. Notably, in 2013, DOE reported to Congress that such activities for a new single, commingled repository would take 28 years to complete.[45] Furthermore, DOE spent 15 years to complete site characterization activities for WIPP, and it took 21 years to complete such activities for Yucca Mountain.[46]

We also found that DOE's estimates for the time frames of certain activities did not adhere to industry best practices for constructing reliable schedule estimates. A reliable, well-constructed schedule is integrated and connects all planned work in a collection of logically linked sequences of activities whose forecasted dates are automatically recalculated when activities change. However, DOE did not provide any documentation about how it calculated its time frames for key activities. In addition, DOE's time frame estimates remain the same regardless of geology or the types of nuclear waste emplaced within either of the two planned repositories. Also, DOE's estimates exclude site selection and site characterization, which could add decades to the time frames, based

[45]The NWPA requires DOE to annually review the Nuclear Waste Fund fee to evaluate whether its collection will provide sufficient revenues to offset the commercial utilities' share of the total life cycle costs of the federal government's disposal activities. As a result of lawsuits, DOE suspended its collection of the Nuclear Waste Fund in 2013 and has also suspended its annual reviews. See Department of Energy, *Nuclear Waste Fund Fee Adequacy Assessment Report* (Washington, D.C.: Jan. 16, 2013).

[46]Site selection time frames for WIPP and Yucca Mountain cannot be directly compared because DOE first planned a single, commingled nuclear waste repository at what is now the WIPP site and eventually negotiated a repository for defense transuranic nuclear waste; in contrast, the Yucca Mountain site was legislatively selected in 1987.

on past DOE experience and plans. These excluded schedule activities could prolong the duration of the project and thereby increase the project's costs. According to the Cost Guide, schedule delays have an effect on the costs of all aspects of a program, such as the costs of additional staff time.

We shared the results of our assessment of DOE's time frame estimates for the two repositories as summarized in DOE's March 2015 report with DOE officials. The DOE officials agreed with our conclusion that, without a fully developed and documented integrated management schedule, it is not possible to evaluate the time frames of certain activities to determine the schedule estimate's reliability. They also said that it was too early to construct a reliable schedule and that the schedule they developed was high-level and based on expert judgment developed from past repository experiences, most notably Yucca Mountain. DOE officials told us that they expect site characterization would not take as long if a site was selected through a consent-based process. We recognize that at the early phases of a project, schedule estimates are preliminary and lack the details applicable to the later stages of project development. However, the level of detail in the schedule should reflect the level of information available according to our Schedule Guide, and DOE excluded time frame estimates for activities where reasonable comparisons exist while providing little support for a schedule estimate that leaves little time for such activities.

DOE Is Planning a Consent-Based Siting Process, but It Has Not Addressed Issues that Are Prerequisite to Siting Considerations

DOE is planning to develop a consent-based siting process for a defense HLW repository with the intention of attaining consent for an eventual repository site. However, DOE likely faces significant opposition and distrust as it develops this process. Moreover, DOE is planning to develop a consent-based siting process before it has addressed certain prerequisites—such as the possible need for EPA to update health and safety regulations—which are necessary to solicit public comment on its consent-based siting process, screen potential sites for a repository, and engage in site selection discussions with local communities.

DOE Is Planning a Consent-Based Siting Process for a Defense HLW Repository

In December 2015, DOE announced plans to solicit public opinion to help develop a consent-based siting process with the ultimate purpose of attaining consent at a site for an eventual repository. DOE planned to collect public input by mail, telephone, various electronic means, and in person at a series of public meetings it planned to hold around the country. As of July 21, 2016, DOE had completed all of its nine scheduled public meetings held at various locations across the country. DOE developed a series of questions to elicit public input and included topics such as how to be fair and who should participate in consent-based siting.[47] DOE announced that, as a result of its public solicitation effort, it had collected more than 10,000 comments; in September 2016, DOE officials issued a report that summarized the public comments it received. DOE announced plans to issue a draft report on the factors it planned to consider for siting nuclear storage or disposal facilities in December 2016. DOE stated that some of the factors it plans to consider include what constitutes consent and who should provide it, socioeconomic issues, and transportation requirements. DOE stated it plans to use these criteria to work collaboratively with potential host communities in selecting a site for a defense HLW repository.

DOE likely faces significant public opposition and distrust as it develops its consent-based siting process. In commenting on DOE's plans to solicit public input on its consent-based siting process, experts representing independent organizations, state entities, and community interest groups identified public opposition as a major obstacle DOE will have to overcome in siting any nuclear disposal or storage facility. In addition, we reviewed transcripts of DOE's meetings and found that participants raised

[47]DOE asked the public to consider interim storage facilities, a defense HLW repository, a subsequent, mostly commercial SNF repository, and deep borehole disposal; DOE also asked the public to address questions such as how to ensure fairness, what models or experience DOE should use in designing a process, and who should be involved in implementation.

the theme of distrust of DOE at every meeting.[48] In summarizing the public comments DOE had received as part of its public solicitation on consent-based siting, DOE reported in September 2016 that a lack of trust and credibility—particularly, lack of trust in DOE—were recurring themes and major impediments to the success of a consent-based siting process.[49] We have previously reported that social and political opposition, not technical issues, are the key obstacles to developing a new repository; we also reported that some stakeholders told us that a final siting decision is inherently a political process and should be made by Congress if the decision is to have any lasting effect.[50]

Despite DOE's commitment to developing a consent-based siting approach, its recent efforts to conduct research on borehole disposal show that it may be underestimating the extent of the public opposition it faces. Specifically, DOE issued a contract for $35 million to conduct research on borehole disposal in Pierce County, North Dakota. Despite DOE's assertions that it had no plans to use the site for future disposal of radioactive waste and that it did not plan to use any nuclear waste in the research, county residents expressed distrust of DOE's long-term intentions. For example, some residents stated that if the research shows boreholes can successfully be used, there were no guarantees that DOE would not dispose of nuclear waste in deep boreholes in the future. The county commission placed a moratorium on permits for deep borehole drilling in the county. DOE's contractor then considered a site in Spink County, South Dakota, to conduct the research. According to DOE, the contractor held public meetings and engaged local elected officials, but the public raised similar concerns and DOE and the contractor mutually agreed to terminate the contract. DOE officials acknowledged that the lack of public support has been a major impediment to conducting research on borehole disposal and, in August 2016, DOE issued a new solicitation that, in part, is to address public opposition by allowing for

[48]For example, in one public meeting we attended in Denver, a former governor of Wyoming spoke about his experience working with DOE on siting a nuclear facility. While governor in 1992, he said he stopped a Wyoming county from hosting an interim storage facility, expressing concerns that despite the assurances of federal officials, he could not be certain that the federal government's attitudes or policies would remain consistent over the next 50 years, and that in the future the federal government might consider making the interim storage facility a permanent one.

[49]See Department of Energy, *Consent-Based Siting: Designing a Consent-Based Siting Process, Summary of Public Input, Draft Report* (Washington, D.C.: Sep. 15, 2016).

[50]GAO-11-229.

early government and public engagement, something that did not happen in DOE's earlier efforts.

DOE Has Not Addressed Certain Prerequisites That Are Needed before It Can Effectively Solicit Public Input, Screen Potential Repository Sites, or Engage Local Communities in Selecting a Site

DOE has not yet addressed certain prerequisites that are needed to develop a site selection process, particularly the health and safety regulations that—as we stated earlier—DOE has said need to be updated. Without updated regulations, the public cannot provide meaningful input into a consent-based siting process, DOE may not be able to effectively screen potential sites for a repository, and local communities cannot be effectively engaged in a meaningful discussion on hosting a nuclear waste repository. For example, current regulations, which were developed in the 1980s, state that for a repository other than Yucca Mountain, the federal government must show that the repository can safely isolate radioactive material for 10,000 years. For Yucca Mountain specifically, regulations require a time period of 1 million years. Since EPA has not yet determined whether or how to update existing standards, EPA officials stated that EPA has not determined the length of time that the federal government must show it can safely store nuclear waste, but they said that EPA would consider requiring a duration longer than 10,000 years. Nevertheless, knowing the time period of compliance is a key prerequisite for the public and potential host communities to have when commenting on siting criteria, for communities to engage in discussions to host a site, or for DOE to screen a site as a potential repository.

Representatives of four state entities told us that DOE may be premature in soliciting public comment for a consent-based siting process because DOE has not yet addressed certain issues that are prerequisites for having discussions with the public and soliciting their input.

Some Key Unresolved Elements that Are Prerequisite to Public Input on Siting Considerations for a Nuclear Waste Repository

In its September 2016 report summarizing public input on a consent-based siting process, the Department of Energy (DOE) identified a number of unresolved elements that are prerequisites for the public to provide meaningful input to developing a site selection process, for communities to engage in discussions with potential host communities, and for DOE to screen potential sites for a repository. Some of these prerequisites are summarized below.

- Current health and safety regulations for a nuclear waste repository other than Yucca Mountain are outdated and need to be revised, but there is uncertainty about when and how the regulations might be updated or what final requirements they might have.
- There is uncertainty about whether DOE or an independent waste management organization would be better suited to develop storage or disposal facilities. DOE officials state that an independent waste management organization would be more effective, but it is not certain how or when—if at all—such an organization might be created.
- There is uncertainty about how much control—in the form of regulatory oversight or enforcement authority—that local communities or states would have over developing and operating a storage or disposal facility.
- There is uncertainty about how to ensure the durability of agreements made over the decades necessary to develop and operate a disposal facility.

Source: GAO analysis of DOE data. | GAO-17-174

In particular, regarding the prerequisite for updating regulations, it is important that regulations are developed before siting a repository to avoid suspicion that the regulations would change to suit the repository. In particular, we found in 2011 that simultaneous development of safety regulations and a license application for Yucca Mountain galvanized opposition against DOE.[51] The Blue Ribbon Commission recognized this risk in its 2012 report, stating that safety regulations—and how to demonstrate compliance with them—should be developed before selecting a site to avoid public suspicion that standards are being adjusted to fit the site.

Experts and stakeholders told us that until such regulations are revised, DOE should not screen potential host communities to determine which ones DOE should enter into discussions with regarding siting. These experts and stakeholders added that it would be premature for DOE to site a defense HLW or a subsequent, mostly commercial SNF repository until health and safety regulations are revised. EPA has responsibility for

[51]GAO-11-229. EPA began developing site specific regulations for Yucca Mountain in 1992. EPA issued a final rule on safety regulations in 2001, but because of a National Academy of Sciences study, multiple lawsuits, and a court remand, EPA did not issue final amendments to that rule until 2008. During this same time, DOE was developing a license application for Yucca Mountain. Nevada state officials told us they believed that DOE had pre-determined that Yucca Mountain was to be found suitable as a repository. The state officials said that not knowing the final regulations created a lot of animosity between DOE and state officials.

revising the regulations, but EPA officials told us that they do not plan to invest resources in revising health and safety regulations without specific direction from Congress. Some attendees of DOE's public solicitation meetings stated that having informed consent was an important element of a consent-based siting process and that lack of information on current health and safety standards did not allow them to provide meaningful consent. If the health and safety standards need to be updated for any future repository other than Yucca Mountain, as we describe earlier in this report, the public cannot provide informed input into a consent-based process if, for example, it does not know what level of protection from exposure will be required.

DOE's project management order requires that prior to approving a mission-related need, DOE perform "pre-conceptual" planning activities, such as safety planning, development of capability gaps, and defining high-level project conditions that are to be attained. DOE officials stated that they did not fulfill all pre-conceptual planning requirements because they do not yet consider the defense HLW repository a project. They told us that they will not consider it a major project until additional planning is conducted on site selection. By not yet completing key pre-conceptual planning activities—namely, what health and safety regulations will apply to siting an eventual repository—it is unclear how DOE can screen potential sites or choose which communities to engage with as part of its new consent-based approach.[52] Moreover, without first knowing what health and safety regulations might apply to a future repository, it is difficult for any member of the public to provide informed input into a consent-based siting process. DOE may risk wasting resources if it screens sites before knowing what health and safety regulations might apply because revisions to such regulations may exclude certain sites that do not meet the requirements, or local communities may oppose hosting a repository once the regulations are revised. If DOE first addresses the need to revise health and safety regulations, it might reduce the risk of public opposition and better ensure that its resources are expended on potential sites that fit its permissible selection criteria. DOE did not provide sufficient information to the President on the prerequisites for developing a consent-based siting process and engaging

[52]DOE has acknowledged it has problems with front-end planning of its major projects. As previously discussed, in November 2014, a senior-level working group found that insufficient front-end planning has consistently contributed to DOE projects not finishing on budget or schedule.

local communities in siting a nuclear waste repository or the amount of time it might take to address these issues.

Conclusions

For decades, the nation has struggled with how to dispose of its inventory of defense-related and commercial HLW and SNF. Since the passage of the NWPA, the nation has spent more than $16 billion to investigate and assess a single, commingled repository, but the prospects of developing a repository do not seem any better now than they did nearly 30 years ago when Yucca Mountain was selected. The information DOE provided to the President in 2015—concluding that a strong basis exists to find that a defense HLW repository is required—served as the basis for the decision that started the nation down the path of developing two repositories. However, the information DOE provided on the estimated costs and schedule was not well-documented, accurate, or credible, and it omitted billions of dollars in expected costs. The information DOE provided to the President also did not quantify benefits, when possible, explain the likelihood of achieving these benefits; or describe the potential impact of costs on future defense budgets. Unlike a single, commingled repository, which would have received most of its appropriations from industry fees, a defense HLW repository will likely have to be fully funded by funds appropriated for the defense budget. Without comprehensively quantifying benefits and calculating the likelihood of achieving them, or fully reflecting all costs and time frames associated with key activities, DOE asked the President to make a decision that could commit the nation to spending tens of billions of dollars and performing decades of work without knowing whether the benefits outweigh the costs, particularly when compared to the benefits and costs of a single, commingled repository.

DOE faces significant public opposition in developing a consent-based siting process and engaging in site selection discussions with local communities, in part because DOE has not yet addressed certain prerequisites that are needed for the site selection process, such as the possible need to revise health and safety regulations. We and others have previously found that the greatest obstacles to the success of any nuclear waste storage or disposal effort are not technical, but social and political—that is, addressing public opposition that has been created by decades of distrust between DOE and the local communities where

nuclear waste repositories may be sited. While seeking the public's input on a siting process may go a long way toward addressing public opposition, DOE is seeking the public's input before the public has all the information it needs. DOE may appear disingenuous if it embarks on a consent-based siting process without first providing information to the public that is a precondition for discussion and that could influence public input. Moreover, DOE may risk wasting resources if it screens sites before knowing what health and safety regulations might apply—essentially putting the cart before the horse—because revisions to such regulations may ultimately exclude certain sites or local communities may oppose hosting a repository if they are uncomfortable with the revised regulations.

Recommendations for Executive Action

We are making two recommendations in this report.

1. The Secretary of Energy should direct the Office of Nuclear Energy to conduct a comprehensive assessment, which adheres to OMB guidance and best practices, of the benefits, costs, and schedules of the options it reviewed and provided to the President in 2015, and, in light of the new information and results of its assessment, revise—if needed—the report's conclusion that a strong basis exists to find that a defense HLW repository is required.
2. The Secretary of Energy should direct the Office of Nuclear Energy to reassess its decision to engage in discussions with potential host communities, screen sites, or conduct other site selection activities until key prerequisites to these efforts—such as revising health and safety regulations—have been addressed.

Agency Comments and Our Evaluation

We provided NRC and DOE with a draft of this report for their review and comment and we provided EPA with relevant excerpts of the draft for its review and comment. NRC provided technical clarifications which we incorporated as appropriate, in addition to written comments, reproduced in appendix V, stating that NRC had no significant comments after reviewing the draft report. EPA did not have any comments on our draft

report, but provided us with technical clarifications which we incorporated as appropriate. DOE provided written comments, which are printed in full in appendix VI, as well as technical comments, which we incorporated as appropriate. In its comments, DOE generally agreed with the intent of our first recommendation, disagreed with our second recommendation, as discussed below.

Regarding our first recommendation, DOE stated that the department agreed that there is a need to understand and evaluate more fully the benefits and costs of a separate repository for defense waste. DOE stated that the presidential finding, as required by section 8 of the NWPA, was necessary before DOE could begin a more detailed analysis of the benefits and costs of a separate defense waste repository. DOE stated that with the Presidential finding, it now plans to acquire the information needed to analyze in greater detail the benefits, risks, costs, and schedule of a separate defense waste repository. In its comments, DOE also stated that the report did not recognize the limited nature of the analysis required by section 8 of the NWPA. We recognize that DOE was at the early stages of its analysis when it recommended to the President that separate repositories be considered, but, as discussed in the report, we believe a more thorough analysis was needed to determine whether such a recommendation should have been made in the first place. Further, the NWPA did not preclude the Department from providing the President that information, particularly a more thorough analysis on whether the benefits of departing from the nation's longstanding nuclear waste storage strategy outweigh the costs. Specifically, we acknowledge in the report that the NWPA only requires an evaluation of six factors, but, as noted above, the NWPA does not preclude DOE from conducting its analysis of benefits and costs in accordance with best practices or its own planning requirements for major acquisitions. As we note in our report, industry best practices apply to cost estimates throughout a project's life cycle, including early, rough-order-of-magnitude estimates. Moving forward, DOE's stated plans to complete detailed analysis and evaluation of the costs, risks, benefits, and schedule is consistent with our recommendation and are imperative to support—or revise as needed—the department's basis for a separate defense HLW repository.

Regarding our second recommendation, DOE disagreed. In its letter, DOE stated that although it agreed that the NRC and EPA regulations governing generic repositories need to be updated, it believed that the consent-based siting process should be initiated as soon as possible to identify one or more volunteer host communities before such updates occur. DOE stated that this parallel approach would support its plans to

begin screening candidate site(s) as early as possible, allowing volunteer communities the opportunity to provide input in the rule-making processes. DOE also noted that establishing a relationship with a community could reduce schedule and cost risks associated with the siting process since detailed cost estimates cannot be made until a community is identified. However, as we stated in our report, the public cannot provide meaningful input into a consent-based siting process without having key information that is a precondition for discussion and which could influence public input. Some of this information includes the status of the health and safety regulations, the degree of local and state regulatory oversight, and the durability of agreements reached. Since we provided our draft report to the department for review and comment, DOE issued draft plans in December 2016 for finalizing a consent-based siting process and developing a defense waste repository. However, DOE's plans to develop a consent-based siting process while simultaneously engaging in site selection discussions with local communities—particularly before addressing key prerequisites that members of the public may need when providing input—may risk compounding public opposition that has been created by decades of distrust between DOE and the local communities over nuclear waste repositories. Therefore, we believe that DOE should reassess its decision to simultaneously pursue such activities until key prerequisites have been addressed.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, the Chairman of the Nuclear Regulatory Commission, the EPA Administrator, the Secretary of Transportation, and other interested parties. In addition, this report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have questions about this report, please contact me at (202) 512-3841 or trimbled@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 VII.

David C. Trimble
Director
Natural Resources and Environment

List of Addressees

The Honorable John McCain
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Deb Fischer
Chair
The Honorable Joe Donnelly
Ranking Member
Subcommittee on Strategic Forces
Committee on Armed Services
United States Senate

The Honorable Thad Cochran
Chairman
The Honorable Richard Durbin
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Lamar Alexander
Chairman
The Honorable Dianne Feinstein
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Mac Thornberry
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Kay Granger
Chairwoman
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

The Honorable Mike Simpson
Chairman
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
House of Representatives

The Honorable Jeff Sessions
United States Senate

Appendix I: Methodology

To assess the benefits that DOE cited in its recommendation to the President about the need for a separate defense HLW repository, we reviewed DOE's March 2015 report and additional planning and cost documents supporting that report.[1] For example, we reviewed DOE's October 2014 report,[2] which DOE used as a basis for developing its March 2015 report. We also interviewed DOE officials in DOE's Office of Nuclear Energy, Office of Environmental Management, Las Vegas field office, and Office of General Counsel, and staff from the Sandia National Laboratories who were familiar with the information presented to the President or who contributed to DOE's March 2015 report and supporting documentation. In addition, we reviewed federal guidance on setting objectives and on planning, budgeting, and acquiring capital assets. Specifically, federal internal controls state that management should identify risks and define risk tolerances for the objectives. Risk tolerance is the acceptable level of variation in performance relative to the achievement of objectives and should be set as part of the objective-setting process. Also, OMB guidance states that when considering a new capital asset, management should assess risks and should determine whether accepting risks are justified considering the return on investment. The guidance also states that benefits and costs should be quantified in monetary terms whenever possible and that all types of benefits and costs should be included. The level of detail should be commensurate with the size and criticality of the investment. The OMB guidance states that certain benefit-cost or cost-effectiveness analysis could be used by senior management to make key decisions. Furthermore, the guidance states that benefits and cost estimates involve some degree of uncertainty and that the risk that a benefit may not be realized as planned should be factored into the cost-benefit analysis.

We also interviewed experts and stakeholders from various entities about the benefits that DOE cited. To ensure balance among the entities, we considered representation among specific categories that GAO had identified and used in prior engagements. These categories covered (1) independent groups and academia, (2) community interest groups, (3) industry, (4) state and local governments, and (5) the federal government. We began interviews with experts and stakeholders in nuclear waste

[1]Department of Energy, *Report on Separate Disposal of Defense High-Level Radioactive Waste*, (Washington, D.C.: March 2015).

[2]Department of Energy, *Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel*, (Washington, D.C.: October 2014).

management from entities we had already identified in our prior work. Before we began each interview, we asked the individual to provide information on his or her background—including education, employment history, and experiences related to nuclear waste management—to assess his or her level of expertise and familiarity with DOE's new plan.[3] Using our professional judgment, we assessed each individual's level of expertise and familiarity in the different issues we considered in our analysis. Opinions of experts on a topic outside their own area of expertise are presented as the opinions of "stakeholders." In some cases, the same individual might be considered an expert in one specific issue, but a stakeholder on another issue. As our interviews progressed, we added other entities to our list based on input from the experts and stakeholders, stopping when we felt information had become repetitive or when we felt no new information could be gained through additional interviews. Once we identified the entities, we contacted individuals within each entity and confirmed their familiarity with the issues. We interviewed 52 experts and stakeholders from 23 entities that represented national organizations with a wide range of viewpoints and expertise on nuclear waste management and disposal issues. The experts and stakeholders from those entities are listed in Appendix IV. To ensure we asked consistent questions among the identified experts and stakeholders, we developed a standard set of questions that included broad questions related to DOE's plan to separately dispose of defense HLW and more specific questions regarding certain elements of DOE's plan.[4] We analyzed the interviews to identify patterns and themes which we reported as appropriate, attributing the responses to the categories of

[3]Specifically, we asked: "Please describe your qualifications regarding radioactive waste management. For example, please describe your education or experience for us. Please specify if you have expertise in cost and schedule estimating, technical areas, or socio-political assessments of radioactive waste management."

[4]We introduced our questions to ask individuals we interviewed to comment on DOE's assumptions in its plan to separately dispose of defense HLW. Specifically, we asked: "We would like you to comment on specific assumptions and milestones in DOE's plan to separately dispose of defense HLW as reported in DOE, *Report on Separate Disposal of Defense High-Level Radioactive Waste* (Washington, D.C.: Mar. 2015). In its report, DOE describes its plan to site, license, construct, and operate two repositories: a defense repository and a commingled repository. The commingled repository plan is based on DOE's 2013 strategy for temporarily storing and disposing of commercial SNF. See DOE, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (Washington, D.C.: Jan. 2013)." Then, we asked questions related to DOE's assumptions, including consent-based siting and site selection, site characterization, and DOE's plan for separate HLW disposal. We asked open-ended questions. We also allowed experts and stakeholders the opportunity to provide input beyond the questions we asked.

people rather than to individuals. Our interviews with experts and stakeholders are nongeneralizable, meaning that opinions cannot be generalized to other experts and stakeholders, either within or across types of expertise.

To assess what is known about the projected costs and schedule of DOE's new plan to site, license, and construct a defense HLW repository, we reviewed DOE reports and documents and interviewed DOE officials about the estimates they developed for DOE's new plan. Regarding the extent to which DOE presented reliable cost estimates in its March 2015 report, we compared DOE's preliminary estimates against the best practices in GAO's Cost Estimating and Assessment Guide (Cost Guide), which has been used to evaluate cost estimates across the government.[5] To develop our assessment, we interviewed DOE officials and contractors who prepared the cost estimates about their cost estimation methodologies and the findings used to support the cost estimates in DOE's March 2015 report. We compared this information with the best practices identified in the Cost Guide to determine whether the cost estimates were (1) comprehensive, (2) accurate, (3) well documented, and (4) credible. After a review of all source data, we assessed the extent to which the cost estimates met these best practices by calculating the assessment rating of each criterion within the four characteristics. After conducting our initial analysis, we shared it with DOE officials to provide them an opportunity to comment and identify reasons for observed shortfalls in cost estimating best practices. We took their comments and any additional information they provided and incorporated them to finalize our assessment. More information about this methodology is provided in Appendix II.

To determine the extent to which DOE developed reliable schedule estimates, we requested information from DOE regarding the development of time frame estimates. We evaluated this information to determine whether the DOE-developed schedules were (1) comprehensive, (2) well-constructed, (3) credible, and (4) controlled. These four characteristics are identified in GAO's Schedule Assessment Guide (Schedule Guide), which is intended to expand on the scheduling concepts introduced in the Cost Guide by providing best practices to help managers and auditors ensure that the

[5]*GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2, 2009).

program schedule is reliable.[6]

To examine DOE's efforts to site a defense HLW repository and to examine siting challenges, if any, we interviewed DOE officials and reviewed DOE reports on previous and current siting efforts. We reviewed transcripts of the public meetings DOE held to solicit public input on a consent-based siting process. DOE held nine meetings during 2016.[7] We attended one of those meetings and reviewed transcripts of all of them. We also reviewed DOE's September 2016 summary of the public input it received. We also reviewed previous GAO reports, as well as relevant reports on siting from other entities, such as the Blue Ribbon Commission on America's Nuclear Future and the National Academies of Science. One of the questions in our standard set of questions focused on DOE's efforts to develop a consent-based siting process.[8] Thus, we solicited input from the experts and stakeholders who we interviewed for our first objective and asked them a standard set of questions on DOE's consent-based siting process, on the specific elements of consent-based siting that should be included or excluded, and the associated challenges with consent-based siting. We also reviewed DOE's project management

[6]*GAO Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

[7]The meetings were held in Atlanta, GA; Boise, ID; Boston, MA; Chicago, IL; Denver, CO; Minneapolis, MN; Sacramento, CA; Tempe, AZ; and Washington, D.C.

[8]Specifically, we asked:
a. In its January 2012 report, the Blue Ribbon Commission on America's Nuclear Future stated that siting "storage or disposal facilities has been the most consistent and intractable challenge for the U.S. nuclear waste management program." The Commission recommended that Congress amend the Nuclear Waste Policy Act to authorize a new consent-based process to be used for selecting and evaluating sites. DOE is now seeking public comment to help design a consent-based siting process that DOE states it plans to use to site both a defense repository and a commingled repository.
b. Though still not designed, what elements do you think a consent-based siting process should include to successfully address the selection and evaluation process for storage or disposal facilities? Specifically, what legislative, regulatory, or procedural elements should be included, if any, to properly develop and implement a process, whether it be consent-based or not, to successfully select and evaluate sites for interim storage or permanent disposal?
c. How would DOE screen viable geologic sites while engaging with potential host communities in a consent-based siting process? Given financial and resource constraints and the time frames involved, what should be the expectations for potential host communities and DOE to resolve these challenges? Please describe the types of benefits and commitments that might be expected from host communities and DOE or other involved parties.

orders regarding “pre-conceptual” planning activities and similar DOE documents indicating the importance of front-end planning.

Appendix II: GAO's Analysis of DOE's Cost Estimates

Background

In a March 2015 report,[1] the Department of Energy (DOE) provided rough-order-of-magnitude cost estimates for (1) a separate defense high-level waste (HLW) repository and (2) a subsequent commingled repository to manage the remaining commercial spent nuclear fuel (SNF) and DOE-managed nuclear waste. DOE had previously published these cost estimates in October 2014.[2] For each of these two cost estimates, DOE provided estimates for different geological media.

Criteria GAO Used for This Analysis

A reliable cost estimate is critical to the success of any program. Such an estimate provides the basis for informed investment decision making, realistic budget formulation and program resourcing, meaningful progress measurement, proactive course correction when warranted, and accountability for results. As we have observed in our GAO Cost Estimating and Assessment Guide (Cost Guide), [3] the Office of Management and Budget (OMB) has set the expectation that programs will maintain current estimates of cost, and cost estimates should encompass the full life cycle of the program. Among other things, the Cost Guide states that the ability to generate reliable cost estimates is a critical function necessary to support OMB's capital programming process. Without this capability, agencies are at risk of experiencing program cost overruns, missed deadlines, and performance shortfalls.

[1]Department of Energy, *Report on Separate Disposal of Defense High-Level Radioactive Waste* (Washington, D.C.: March 2015).

[2]Department of Energy, *Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel* (Washington, D.C.: October 2014). In addition to the cost estimates for a separate repository for defense HLW, this report also provided two other cost estimates for disposing of defense HLW in a separate repository along with other forms of defense-related nuclear waste, such as with highly radioactive SNF from defense activities.

[3]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: May 16, 2013).

We performed a summary analysis by combining the best practices for sound cost estimating into four general characteristics. Our research has identified cost estimating best practices in the GAO Cost Estimating and Assessment Guide (Cost Guide).[4] We conducted a summary, or abridged, analysis by summarizing portions of the best practices because DOE's cost estimate were early in the acquisition life cycle. While rough order of magnitude estimates should never be considered high-quality estimates, rough-order-of-magnitude estimates can be considered reliable by fully or substantially meeting industry best practices. For example, we have found that other rough order of magnitude estimates substantially or fully met various characteristics of a reliable cost estimate, such as cost estimates prepared by the Department of Defense[5] and the U.S. Customs and Border Protection within the Department of Homeland Security.[6] Moreover, DOE cost guidance states that, "regardless of purpose, classification, or technique," DOE cost estimates should demonstrate quality sufficient for its intended use, be complete, and follow accepted standards such as GAO's Cost Guide.[7] DOE's cost guidance also describes good cost estimates as including a full life-cycle cost estimate, among other things. These best practices should result in reliable and valid cost estimates that management can use for making informed decisions. According to GAO's Cost Guide, the four characteristics of a reliable cost estimate are:

- ***Comprehensive:*** The cost estimate should include both government and contractor costs of the program over its full life cycle, from inception of the program through design, development, deployment, and operation and maintenance to retirement of the program. It should also completely define the program, reflect the current schedule, and be technically reasonable. Comprehensive cost estimates should be structured in sufficient detail to ensure that cost elements are neither omitted nor double counted. Specifically, the cost estimate should be based on a product-oriented work breakdown structure (WBS) that allows a program to track costs and schedule by defined deliverables, such as hardware or software components. Finally, where information

[4]GAO-09-3SP.

[5]GAO, *Spectrum Management: Federal Relocation Costs and Auction Revenues*, GAO-13-472 (Washington, D.C.: May 22, 2013).

[6]GAO, *Arizona Border Surveillance Technology: More Information on Plans and Costs Is Needed before Proceeding,* GAO-12-22 (Washington, D.C.: Nov. 4, 2011).

[7]*DOE Cost Estimating Guide*, DOE Order 413.3-21 (Washington, D.C.: May 9, 2011).

is limited and judgments must be made, the cost estimate should document all cost-influencing ground rules and assumptions.

- ***Well-documented:*** A good cost estimate—while taking the form of a single number—is supported by detailed documentation that describes how it was derived and how the expected funding will be spent in order to achieve a given objective. Therefore, the documentation should capture in writing such things as the source data used, the calculations performed and their results, and the estimating methodology used to derive each WBS element's costs. Moreover, this information should be captured in such a way that the data used to derive the estimate can be traced back to and verified against their sources so that the estimate can be easily replicated and updated. The documentation should also discuss the technical baseline description and how the data were normalized. Finally, the documentation should include evidence that the cost estimate was reviewed and accepted by management.
- ***Accurate:*** The cost estimate should provide for results that are unbiased, and it should not be overly conservative or optimistic. An estimate is accurate when it is based on an assessment of most likely costs, adjusted properly for inflation, and contains few, if any, minor mistakes. In addition, a cost estimate should be updated regularly to reflect significant changes in the program—such as when schedules or other assumptions change—and actual costs, so that it is always reflecting current status. During the update process, variances between planned and actual costs should be documented, explained, and reviewed. Among other things, the estimate should be grounded in a historical record of cost estimating and actual experiences on other comparable programs.
- ***Credible:*** The cost estimate should discuss any limitations of the analysis because of uncertainty or biases surrounding data or assumptions. Major assumptions should be varied and other outcomes recomputed to determine how sensitive they are to changes in the assumptions. Risk and uncertainty analysis should be performed to determine the level of risk associated with the estimate. Further, the estimate's cost drivers should be crosschecked, and an independent cost estimate conducted by a group outside the acquiring organization should be developed to determine whether other estimating methods produce similar results.

Limitations to the Analysis

DOE intended its rough-order-of-magnitude cost estimates to support a legal determination and spark discussion, and not to be rigorous milestone cost estimates, according to DOE officials. As a result, DOE's cost estimation documentation may not be compiled as would be standard practice for a more rigorous cost estimate. As stated previously, it is our practice to conduct a summary analysis in cases in which the agency develops and provides cost estimates early in the acquisition life cycle, such as for DOE's rough order of magnitude estimates.

Summary of DOE's Methods for its Rough-Order-of-Magnitude Cost Estimates

DOE's March 2015 report provided rough-order-of-magnitude cost estimates for (1) a separate defense HLW repository and (2) a subsequent repository to dispose of commercial SNF and DOE-managed nuclear waste (which DOE described as a "Common NWPA Repository excluding Defense HLW"). For each of these two cost estimates, DOE provided estimates for five different geological media (crystalline, bedded salt, clay/shale, shale unbackfilled, and sedimentary unbackfilled). The cost estimates provided estimates for some activity phases of the life-cycle costs for developing a geological repository (design, construction, start-up, operations, closure, and monitoring), but other phases of the life-cycle cost, such as storage, transportation, siting, and other tasks were excluded.

As DOE stated in its report to the President, the combined cost of two repositories is generally greater than one. Table 5 below displays DOE's March 2015 cost estimates for two separate repositories. For comparison, table 5 also shows DOE's estimates for a single repository to dispose of all nuclear waste.

Table 5: The Department of Energy's (DOE) Rough-Order-of-Magnitude Cost Estimates Provided to the President for Developing Two Separate Repositories (in billions of 2013 dollars)

	Individual costs of two separate nuclear waste repositories				Combined cost of two separate repositories (GAO calculation)		Costs of single, commingled repository	
	Costs of defense high-level waste repository[a]		Costs of second, mostly commercial SNF repository[b]				Disposal costs for all nuclear waste	
Geology of repository	Low	High	Low	High	Low (Total)	High (Total)	Low	High
Crystalline (such as granite)	34[c]	44	64	85	**98**	**129**	73	96
Clay/Shale	33[c]	44[c]	63	84	**96**	**128**	71	95
Sedimentary backfilled	18[c]	24[c]	34	45	**51**	**69**	38	51
Shale (not backfilled)	14	19[c]	27	36	**41**	**55**	30	40
Bedded Salt	13	18	25	34	**38**	**52**	29	39

Source: GAO analysis of Department of Energy data. | GAO-17-174

[a]According to DOE officials, if past practice continues, the entire cost of a defense HLW repository would likely be paid with defense appropriations.

[b]According to DOE officials, most of the costs of a subsequent, mostly commercial SNF repository would be paid from the Nuclear Waste Fund, but because a small portion of the waste is of defense origin, some percentage of the repository costs would also likely be paid with defense appropriations.

[c]This figure is corrected from DOE's March 2015 report to the President, because the original figure contained a minor rounding error—specifically, this figure was originally rounded down instead of up. DOE corrected these errors when it provided us with the calculations for its estimates.

Note: GAO found that these DOE rough-order-of-magnitude cost estimates were not reliable because they excluded major costs that will likely add tens of billions of dollars, were minimally documented, lacked transparency, and were not fully credible.

DOE's cost estimates indicate that developing two separate repositories is about one-third higher than the costs to develop a single commingled repository in a similar geology. This is partly because some costs would be spent twice—once for each repository. However, DOE's cost estimates understated this cost difference because DOE omitted certain costs from its estimates that must be spent for each separate repository. For example, DOE omitted the costs of selecting and characterizing separate sites, which would be in the tens of billions of dollars for each repository, according to DOE documents and its past experiences in developing geologic repositories at Yucca Mountain and in New Mexico. If the nation develops separate repositories, these costs would be spent again for each separate repository. Because DOE did not include the costs of selecting and characterizing sites for separate repositories, DOE

understated the costs that would result from developing separate repositories. As a result, decision-makers are unable to directly compare DOE's cost estimates for separate repositories with its cost estimates for a single, commingled repository.

DOE provided GAO with supporting documentation for the cost estimates DOE presented in its March 2015 report:

- A published November 2012 DOE report (Hardin et al. 2012) provides estimates of SNF repository costs in five different geologies (salt, crystalline, clay/shale, shale open, sedimentary).[8]
- A draft, unpublished July 2012 DOE report (Carter et al. 2012) provides estimates of a separate defense HLW repository in one geology (salt).[9]
- A published January 2013 DOE report compared the cost of disposing of current and future nuclear waste volumes with future receipts of the nuclear waste fund.[10]
- An October 2015 spreadsheet, transmitted directly to GAO, details how DOE officials used the reports described above to calculate the cost estimates for both the defense HLW repository and the subsequent repository for commercial SNF and DOE-managed nuclear waste that it presented to the President and published in its March 2015 report.[11]

[8]Hardin, Ernest, T. Hadgu, D. Clayton, R. Howard, H. Greenberg, J. Blink, M. Sharma, M. Sutton, J. Carter, M. Dupont, and P. Rodwell, *Repository Reference Disposal Concepts and Thermal Load Management Analysis*, FCRD-UFD-2012-00219 (2nd Revision) (Washington, D.C.: U.S. Department of Energy, Office of Used Nuclear Fuel Disposition, Sandia National Laboratories: November 2012).

[9]Carter, Joe T., P.O. Rodwell and B. Robinson, *Costing Study for a Generic Salt Repository: Systems Engineering and Analysis in Support of a Policy Review of Comingling Decision and Related System Design Considerations: Fuel Cycle Research and Development*, FCRD-UFD-2012-000113 Rev. 1 (Washington, D.C.: U.S. Department of Energy, July 2012). DOE has restricted this report from public access.

[10]Department of Energy, *Nuclear Waste Fund Fee Adequacy Assessment Report* (Washington, DC: Jan. 16, 2013).

[11]This spreadsheet, file name "*GAO_DWR Audit_Cost Basis for Oct2014 Table 3.xlsx,*" was transmitted by e-mail from DOE to GAO on October 7, 2015.

GAO Analysis Summary

Based on this analysis, we determined that DOE's cost estimate are not reliable. A cost estimate is considered reliable if the overall assessment ratings for each of the four characteristics are substantially or fully met. If any of the characteristics are not met, minimally met, or partially met, then the cost estimate does not fully reflect the characteristics of a high-quality estimate and cannot be considered reliable. Our review accounted for the nuclear waste repository estimates' early stage in the typical DOE acquisition management system for other capital asset projects. After reviewing documentation DOE submitted for its cost estimates, conducting numerous interviews, and reviewing relevant sources, we determined that the DOE's rough-order-of-magnitude cost estimates minimally met two of the four characteristics of a reliable cost estimate, and partially met two of these four characteristics.

- **Comprehensive:** Partially met. To determine whether an estimate is comprehensive, we examine whether the cost estimate includes all life cycle costs, including both government and contractor costs required to develop, produce, deploy, and sustain a particular program. In addition, we examine whether an objective review was performed to certify that the estimate's criteria and requirements have been met, since they create the estimate's framework. This step also infuses quality assurance practices into the cost estimate. In this effort, the reviewer checks that the estimate captures the complete technical scope of the work to be performed, using a logical WBS that accounts for all criteria and requirements. In addition, we examined whether assumptions and exclusions on which the estimate is based are clearly identified, explained, and reasonable.
- **Well-documented:** Minimally met. To determine whether an estimate is well-documented, we examine whether the cost estimate's documentation explicitly identifies the primary methods, calculations, results, rationales or assumptions, and sources of data used to generate each cost element. Furthermore, we assess whether the documentation justifies all assumptions and describes each estimating method (including any cost estimating relationships) for every WBS element. Also, we determine whether the documentation was detailed enough so that the derivation of each cost element can be traced to all sources, allowing for the estimate to be easily replicated and updated. Best practices state that documentation of management approval demonstrates that upper management has been made aware of the approach to the cost estimate, its risks and

uncertainties, and its strengths and limitations. Without this, agencies cannot demonstrate that their management was made aware of these considerations regarding the reliability of the estimates.

- **Accurate:** Partially met. Validating that a cost estimate is accurate requires thoroughly understanding and investigating how the cost model was constructed. For example, we checked cost elements to verify that calculations are accurate and account for all costs, including indirect costs. Moreover, proper escalation factors should be used to inflate costs so that they are expressed consistently and accurately. Checking spreadsheet formulas, databases, or cost model data inputs is imperative to validate cost model accuracy. Besides the basic checks for accuracy, we reviewed the estimating technique used for cost elements. Presenting a range of potential costs that has a clear link to a factor of confidence helps express a degree of uncertainty about the estimate. Using a risk and uncertainty analysis as the basis for a range of potential costs and contingency reserves improves decision makers' understanding of an estimate's accuracy.[12]
- **Credible:** Minimally met. To determine an estimate's credibility, key cost elements should be tested for sensitivity, and other cost estimating techniques should be used to cross-check the reasonableness of the ground rules and assumptions. It is also important to determine how sensitive the final results are to changes in key assumptions and parameters. A sensitivity analysis identifies key elements that drive costs and permits what-if analyses, often used to develop cost ranges and risk reserves.

Additional details are provided in table 6 (below).

Table 6: Summary Assessment of the Department of Energy's (DOE) Nuclear Waste Repository Cost Estimates Compared to GAO Best Practices

Characteristic and Overall Assessment	Best Practice	GAO Assessment of DOE Cost Estimates
Comprehensive Partially Met	Estimate includes all life cycle costs, completely defines the program, reflects the current schedule, and is technically reasonable.	DOE excluded significant life cycle costs from the estimates.

[12]Contingency reserves are funds held at or above the government program office for "unknown unknowns" that are outside the project developer's control.

	The WBS is product-oriented, traceable to the statement of work/objective, and at an appropriate level of detail to ensure cost elements are neither omitted nor double-counted.	There is a WBS in one supporting document—the November 2012 report—but no clear documentation shows how the WBS was used to support the March 2015 report.
	All cost-influencing ground rules and assumptions are documented.	Assumptions are documented in some cases, but not others.
Well-documented Minimally Met	The documentation should capture the source data used, the reliability of the data, and how the data were normalized. The documentation describes in sufficient detail the calculations performed and the estimating methodology used to derive each element's costs. The documentation describes step by step how the estimate was developed so that a cost analyst unfamiliar with the program could understand what was done and replicate it.	Most, but not all, source data is captured in the documentation. DOE officials responded that the source data and calculations could be found in the source documentation used to derive the estimates. However, the source documentation did not describe either the calculations performed or the estimating methodology used to derive each element's cost. DOE officials told us that they had not retained the original documents used to calculate the estimates. As a result, DOE had to re-create the calculations for GAO.
	The documentation discusses the technical baseline description, and the data in the baseline is consistent with the estimate.	The technical description is documented in source documents, but does not appear in the report.
	The documentation provides evidence that the cost estimate was reviewed and accepted by management.	GAO requested, but DOE did not provide, documentation showing that its cost estimates were approved by DOE management prior to their submission to the President. It is not known how or whether management approved the report prior to its release.
Accurate Partially Met	The cost estimate results are unbiased, not overly conservative or optimistic, and based on an assessment of most likely costs.	DOE did not calculate a confidence level for its cost estimates, so it is impossible to determine whether it is overly conservative or optimistic. In particular, DOE did not calculate its cost estimate ranges by clearly linking them with the risk and uncertainty of the cost estimates, as called for by industry best practices and DOE's cost estimation guidance.[a] Rather, DOE set the high and low ranges of its cost estimates by using predetermined factors—specifically, assuming a predetermined amount of contingency unconnected with any estimate of risk and uncertainty. DOE officials stated that at this stage, DOE does not have the detail to calculate quantitative confidence levels, and the officials reiterated that they used a predetermined amount of contingency instead of using confidence levels to set contingency levels. As a result, decision makers cannot know how much confidence they should have in DOE's estimates.
	The estimate has been adjusted properly for inflation.	The estimates took inflation into account.

	The estimate contains few, if any, minor mistakes.	DOE's estimates appear to contain a few minor errors related to rounding. DOE discovered and corrected a few minor rounding errors that were in the estimates provided to the President.
	The cost estimate is regularly updated to reflect significant changes in the program so that it is always reflecting current status.	The estimates have not been updated yet, likely because the program is in an early stage of development.
	Variances between planned and actual costs are documented, explained, and reviewed. The estimate is based on a historical record of cost estimating and actual experiences from other comparable programs.	Because of how early it is in the program, there is no variance between planned and actual costs. The estimates are based on historical estimates.
Credible Minimally Met	The cost estimate includes a sensitivity analysis that identifies a range of possible costs based on varying major assumptions, parameters, and data inputs. A risk and uncertainty analysis was conducted that quantified the imperfectly understood risks and identified the effects of changing key cost driver assumptions and factors.	The cost estimates do not include a sensitivity analysis. A risk and uncertainty analysis was not conducted.
	Major cost elements were cross-checked to see whether results were similar.	Major cost elements were not cross-checked.
	An independent cost estimate was conducted by a group outside the acquiring organization to determine whether other estimating methods produce similar results.	DOE stated that it was too early to conduct an independent cost estimate, although a peer review was done.

Source: GAO analysis of DOE data. | GAO-17-174

[a]Under DOE and GAO guidance, a risk and uncertainty analysis should be used to calculate a range of potential cost values at different probability levels, and the costs that correspond to those probability levels determine the level of contingency. In contrast, DOE did not conduct a risk and uncertainty analysis. As a result, DOE set its contingency level without any connection to risk and uncertainty levels. For specific guidance, see Department of Energy Cost Estimating Guide, DOE Order 413.3-21 (Washington, D.C.: May 9, 2011), 51-56, and GAO-09-3SP, 156-9.

Appendix III: Timeline of Key Events in Managing Nuclear Waste, 1983-2015 (Text for Interactive Figure 1)

1980s	1983	**The President signed the Nuclear Waste Policy Act of 1982 (NWPA)**. The act directed, among other things, that (1) the Department of Energy (DOE) study sites for a repository, (2) DOE contract with industry to begin taking title to and disposing of commercial spent nuclear fuel (SNF) in 1998; and (3) the President evaluate the capacity for the disposal of high-level radioactive waste (HLW) resulting from atomic energy defense at one or more repositories developed for the disposal of commercial SNF.
	1984	**The Department of Energy (DOE) issued environmental assessments on nine sites considered for a repository.** Under NWPA, DOE was to assess various sites and recommend the best sites for further study. Six sites were in the West and three were in the South.
	1985	**After conducting a Section 8(b)(1) of NWPA evaluation, President Reagan found that there was no basis to conclude that a separate defense HLW repository was required.**
	1986	**DOE recommended three sites for further study for the nation's first repository.** Of the nine sites studied, the Secretary of Energy recommended to the President three sites for further study: Yucca Mountain, NV; Deaf Smith County, TX; and Hanford, WA.
	1987	**Congress amended the NWPA to direct DOE to investigate only Yucca Mountain for a national repository.** The amendment also directed that funding for other candidate sites be phased out. Opponents referred to this amendment as the "Screw Nevada" bill and used it to galvanize opposition to a repository at Yucca Mountain.
1990s	1998	**DOE missed the contractual deadline called for in NWPA to begin taking title to and disposing of commercial spent nuclear fuel (SNF).** DOE issued a "viability assessment" reporting that DOE still considered Yucca Mountain to be a viable repository site. However, DOE's inability to take custody of commercial SNF for disposal resulted in industry lawsuits against DOE.
2000s	2002	**Congress approved Yucca Mountain as the site for a national repository.** As per the process outlined in the NWPA, DOE recommended to the President approval of the Yucca Mountain site as a national repository; the then-President recommended the site to the Congress. The Governor of Nevada submitted a notice of disapproval; and Congress effectively overrode the disapproval by joint resolution.
	2008	**DOE submitted a license application to the Nuclear Regulatory Commission (NRC) for the construction of a permanent repository at Yucca Mountain.** Under NWPA, the NRC had three years—which could be extended by a year if needed—to review the license and issue a final decision approving or disapproving the issuance of a construction authorization for a repository at Yucca Mountain. Additional legislation would be needed to begin any actual construction, if the NRC approved the license application.
2010s	2010	**DOE terminated its efforts to license the Yucca Mountain repository and established the Blue Ribbon Commission on America's Nuclear Future, at the President's direction, to review alternatives.** DOE submitted a motion to the NRC's Atomic Safety and Licensing Board to withdraw its license application, but the Board denied DOE's motion. Acting on directions from the President, DOE established the Blue Ribbon Commission and directed that the commission conduct a comprehensive review of policies for managing nuclear waste, including defense and commercial SNF and HLW.
	2011	**NRC suspended its review of DOE's license application for Yucca Mountain.**

2012	**The Blue Ribbon Commission issued its report.** The commission's report recommended, among other things, that DOE adopt a new consent-based adaptive approach to siting and developing nuclear waste facilities, and that a new organization be created to implement the waste management program. However, the commission reported that it did not have the time or resources necessary to evaluate whether a new organization should manage defense waste or whether defense and commercial waste should be commingled. The commission urged the administration to review these issues.
2013	**DOE issued a new strategy based on the Blue Ribbon Commission's recommendations.** DOE's strategy included temporary storage of SNF at two interim storage sites and disposal of defense and commercial HLW and SNF in a single, commingled repository. NRC resumed its review of the Yucca Mountain license under an order from the U.S. Court of Appeals.
2014	**DOE issued a technical study on various options for disposal of defense HLW and SNF.** The October 2014 report evaluated three primary disposal options, which included (1) a single commingled repository for all defense and commercial waste, (2) two repositories, one primarily for defense waste and one primarily for commercial SNF, and (3) boreholes for the disposal of smaller waste forms.
2015	**The President found that a separate repository for defense HLW and SNF was required.** A March 2015 report summarized the information that was provided to the President to support the Presidential finding. Separately, in January, the NRC generally found that DOE's license application for Yucca Mountain met nearly all applicable regulations. The NRC must still complete a separate adjudicatory process which could take several more years and cost about $330 million, according to the NRC.

Source: GAO analysis of DOE and NRC data. | GAO-17-174

Appendix IV: Experts and Stakeholders We Interviewed

Table 7: Experts and Stakeholders We Interviewed for This Report

Name	Affiliation
Rod Baltzer	Waste Control Specialists, LLC
Lake Barrett	L. Barrett Consulting
Paul Bembia	New York State Energy Research and Development Authority
William Boyle	Department of Energy
Ivana Brancaccio	Energy Communities Alliance
Nancy Buschman	Department of Energy
Kara Colton	Energy Communities Alliance
Joel Dorfman	Nuclear Regulatory Commission
Steven Kraft	Nuclear Energy Institute
Susan Crockett	Eddy County, New Mexico
Martha Crosland	Department of Energy
Kevin Crowley	National Research Council, National Academy of Sciences
Alan Denko	Department of Navy
Rodney Ewing	Nuclear Waste Technical Review Board
Geoffrey (Geoff) Fettus	Natural Resources Defense Council
Tim Frazier	TA Frazier and Associates, LLC
Maury Galbraith	Western Interstate Energy Board
Jerry Goad	Colorado Department of Public Health and Environment
Adam Gendelman	Nuclear Regulatory Commission
Steve Gomberg	Department of Energy
Andrew Griffith	Department of Energy
Tim Gunter	Department of Energy
John Heaton	Eddy-Lea Energy Alliance, LLC
Lisa Janairo	The Council of State Governments, Midwestern Office
Hank Jenkins-Smith	University of Oklahoma
Seth Kirshenberg	Energy Communities Alliance
Bret Leslie	Nuclear Waste Technical Review Board
Edwin Lyman	Union of Concerned Scientists
Arjun Makhijani	Institute for Energy and Environmental Research
James Maltese	Nuclear Regulatory Commission
Christopher Markley	Nuclear Regulatory Commission
Dan Metlay	Nuclear Waste Technical Review Board
Ann McCabe	National Association of Regulatory Utility Commissioners
Tim McCartin	Nuclear Regulatory Commission
Rodney (Rod) McCullum	Nuclear Energy Institute

Katrina McMurrian	Nuclear Waste Strategy Coalition
Katie Meehan	National Conference of State Legislatures
Nigel Mote	Nuclear Waste Technical Review Board
Cyrus Nezhad	Department of Energy
Pierre Paul Oneid	Holtec International, Inc.
Jennifer Opila	Colorado Department of Public Health and Environment
Tammy Ottmer	Colorado Department of Public Health and Environment
Everett Redmond	Nuclear Energy Institute
Jim Reed	National Conference of State Legislatures
Jim Rubenstone	Nuclear Regulatory Commission
Daniel Schultheisz	Environmental Protection Agency
Kaitlin Sweeney	Nuclear Energy Institute
Kim Tyrrell	National Conference of State Legislatures
Jack Volpato	Eddy-Lea Energy Alliance, LLC
Jim Williams	Western Interstate Energy Board
Sam Walsh	Department of Energy
Shelly Wilson	South Carolina Department of Health and Environmental Control

Source: GAO | GAO-17-174

Appendix V: Comments from the Nuclear Regulatory Commission

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

January 6, 2017

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

Dear Mr. Trimble:

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-17-174, "Nuclear Waste: Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste."

The report recommends that the U.S. Department of Energy comprehensively assess benefits, costs, and schedule for its proposed options, and address key prerequisites needed for the site selection process before engaging potential local communities and embarking on site selection activities. The report discusses NRC's role in regulating potential disposal facilities. The NRC has reviewed the report and has no significant comments for GAO's consideration.

If you have any questions regarding the NRC's response, please contact Mr. John Jolicoeur by phone at (301) 415-1642 or by e-mail at John.Jolicoeur@nrc.gov.

Sincerely,

Victor M. McCree
Executive Director
for Operations

Appendix VI: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

January 10, 2017

Mr. David C. Trimble
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, D.C. 20548

Dear Mr. Trimble:

Thank you for providing a draft copy of the Government Accountability Office (GAO) report, "*Nuclear Waste: Benefits and Costs Should be Better Understood Before DOE Commits to a Separate Repository for Defense Waste*" (GAO-17-174). We appreciate GAO's efforts to review our programs.

We agree, as your report title suggests, that there is a need to understand and evaluate more fully the benefits and costs of a separate repository for defense waste. Consistent with Section 8 of the Nuclear Waste Policy Act of 1982, as amended, the March 2015 Presidential finding authorized the Department of Energy (DOE) to move forward with planning for a separate repository for the disposal of high-level radioactive waste resulting from atomic energy defense activities. The decision to move forward with planning for the separate disposal of defense high-level radioactive waste offers greater flexibility and optionality in developing programmatic pathways for the disposal of such waste. Indeed, it is this planning process that will allow DOE to analyze and evaluate the costs and benefits of this potential path forward as GAO recommends; this detailed analysis could only proceed following the March 2015 Presidential finding.

The draft report fails to recognize the limited nature of the analysis required by Section 8 of the NWPA, and that further, more detailed analysis could only be started once the finding required under Section 8 was made. The significance of the Presidential finding is that it provides optionality and allows DOE to go forward with the planning process and detailed analysis that the draft GAO report recommends. DOE is moving forward under our current authority to acquire the information needed to analyze in greater detail the benefits, risks, costs, and schedule of a separate repository.

Initial analysis suggests that a separate repository for defense waste may be desirable and cost-effective. Since the Cold War is over and the United States is no longer generating defense high-level radioactive waste associated with weapons production, a known quantity of waste now exists in different forms that are largely defined, providing a firm baseline to examine the opportunities for separate disposal pathways for these waste forms. Some of this defense high-level radioactive waste is less radioactive, cooler, and easier to handle than commercial spent nuclear fuel, which could mean a simpler design and potentially fewer licensing and transportation challenges for a separate defense repository. Separate disposal of defense high-level radioactive waste could also allow greater flexibility in site selection – and that could help keep costs down.

The potential for earlier availability of a defense high-level radioactive waste repository would provide greater assurance that DOE can meet current legally-binding requirements for movement of defense waste, avoiding the potential for significant future fines and penalties as well as costs for continuing storage, treatment, and management for waste currently stored at DOE facilities. Finally, moving forward with a repository that may have a simpler design and present fewer licensing challenges in the near-term could reduce the overall cost and time required to develop future repositories through the experience gained in design, siting, licensing, and development.

The draft GAO report notes that there is limited information available at this time to develop a detailed project baseline or a life cycle cost estimate for a defense repository. But the GAO report confuses the requirements for preparing a life-cycle cost estimate for the acquisition of a capital project, as specified in Departmental Orders, and what was required for the Department's analysis of the six factors specified under Section 8 of the NWPA. The Department has repeatedly stressed to GAO that the purpose of its analysis under Section 8 was to assess specific discriminators to make findings on the potential benefits of a defense waste repository as compared to a common repository for both commercial and defense waste. The further definition of the project, including development of a detailed project baseline and life cycle cost estimate, is not required for the Section 8 finding, and in fact, could not appropriately be undertaken until the Presidential finding was made. We also point out that the Presidential finding is not an irreversible commitment to a separate defense repository; rather it is a necessary condition to enable DOE to examine the optionality of a separate repository, including developing the necessary analyses that the draft GAO report recommends.

On December 19, 2016, DOE issued a "*Draft Plan for a Defense Waste Repository*" for public comment. It addresses all of the elements needed for an evaluation of life-cycle considerations for a defense repository. We believe that this planning process is the necessary next step toward completion of the detailed analysis and evaluation of the costs and benefits needed to make informed decisions about the value of a defense repository as part of an integrated waste management system and to confirm that proceeding with a defense waste repository is in the Nation's best interest. The current approach is flexible and adaptive and does not commit the DOE to building a defense repository.

Ultimately, a decision to build a defense repository will be based on not only this detailed analysis and evaluation, but also important factors including technical and institutional issues related to siting a facility. The decision by the President to authorize DOE to move forward with planning for a separate repository recognized that the path to a common repository has been significantly more controversial, costly and delayed than was anticipated in 1985. Against this backdrop, initial analysis suggests that a separate defense repository may be a desirable and cost-effective option, particularly when all of these factors are taken into consideration. Life cycle cost ultimately depends on schedule, which has over time been shown to be unpredictable and subject to change. This history is precisely what merits investigation of multiple options. Our 30 years of experience in siting nuclear waste facilities suggest that a different approach is warranted. Our efforts are consistent with the recommendations of the Blue Ribbon Commission on America's Nuclear Future and aim to provide future Administrations with options for addressing nuclear waste.

The Department's specific responses to each recommendation and our clarification of facts are attached. If you have any questions, please contact me or Ms. Kelly Glanz at kelly.glanz@nuclear.energy.gov or (202) 586-4288.

Sincerely,

Raymond Furstenau
Acting Assistant Secretary
for Nuclear Energy

Attachment

Recommendation 1: The Secretary of Energy should direct the Office of Nuclear Energy to conduct a comprehensive assessment, which adheres to OMB guidance and best practices, of the benefits, costs, and schedules of the options it reviewed and provided to the President in 2015, and in light of the new information and results of the assessment, revise – if needed – the report's conclusion that a strong basis exists to find that a defense HLW repository is required.

We agree with the GAO that significant uncertainty exists in the March 2015 ROM estimate in assessing the required factors under Section 8 of the NWPA, including the cost analysis.

DOE has requested funding from the Congress to initiate the consent-based siting process for a defense repository. Among many benefits, it will allow us to perform more reliable cost estimates based on a detailed design for a specific host site and geology, consistent with OMB and GAO guidance. A defense repository offers the potential to develop an operating repository sooner than a common repository since the characteristics of defense HLW allow a simpler design. Opening a repository sooner could offer the DOE's cleanup mission significant cost reduction/avoidance opportunities; lessons learned could inform the development of a common repository and test a consent-based siting process that has succeeded in other countries to site nuclear waste facilities. Should the results of a more detailed cost benefits analysis indicate that pursuit of one or more common repositories is more advantageous, work on a defense repository could be suspended. However, more than one repository will likely be needed. As you note in the subject report, the 1982 NWPA required at least two repositories for commercial spent nuclear fuel (SNF) so that "no one single state would bear the long-term disposal obligations for the entire nation's commercial SNF."

Recommendation 2: The Secretary of Energy should direct the Office of Nuclear Energy to reassess its decision to engage in discussions with potential host communities, screen sites, or conduct other site selection activities until key prerequisites to these efforts – such as revising health and safety regulations – have been addressed.

DOE does not agree with this recommendation. Although we agree that the NRC and EPA regulations governing generic repositories need to be updated, we believe that the consent-based siting process should be initiated as soon as possible to identify one or more volunteer host communities prior to finalizing the updated regulations. This parallel approach would support DOE plans to begin screening candidate site(s) as early as possible, and allow the volunteer communities the opportunity to provide input during the rule-making processes.

Since detailed cost estimates cannot be made until a host community has been identified, establishing a working relationship with a willing and informed community could reduce the schedule and cost risks associated with the siting process and potentially allow us to build a repository sooner.

The DOE believes pursuit of a defense repository bears merit, particularly in advancing the cleanup of our Cold War sites, but the DOE has not irrevocably committed to building a defense repository.

Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

David C. Trimble, (202) 512-3841 or trimbled@gao.gov

Staff Acknowledgments

In addition to the individual named above, Nathan Anderson, Assistant Director; Kevin Bray; Mark Braza; Martin G. Campbell; Lee Carroll; Jennifer Echard; Emile Ettedgui; Robert S. Fletcher; Cristian Ion; Katrina Pekar-Carpenter; Karen Richey; Robert Sanchez; Dan C. Royer; and Jack Wang made key contributions to this report.

Appendix VIII: Accessible Data

Data Table for Figure 4:

Single, commingled repository		Separate repositories	
		Mostly commercial spent nuclear fuel:	
low range:	29	low range: ($0 to 25)	25
High range ($29-$96)	67	High range ($25 to 85)	60
		Defense high-level waste:	
		low range ($0-13)	13
		High range ($13-44)	31

Data Table for Figure 5:

Year	Low cost estimate for DHLW repository (Salt)	Low cost estimate for DHLW repository (Crystalline)
1	0.41	1.31
2	0.41	1.31
3	0.41	1.31
4	0.22	0.74
5	0.18	0.61
6	0.18	0.61
7	0.18	0.61
8	0.18	0.61
9	0.51	1.74
10	0.51	1.74
11	0.51	1.74
12	0.51	1.74
13	0.51	1.74
14	0.51	1.74
15	0.51	1.74
16	0.15	0.50
17	0.15	0.50
18	0.15	0.50
19	0.15	0.50
20	0.15	0.50
21	0.15	0.50
22	0.15	0.50
23	0.15	0.50
24	0.15	0.50

25	0.15	0.50
26	0.15	0.50
27	0.15	0.50
28	0.15	0.50
29	0.15	0.50
30	0.15	0.50
31	0.15	0.50
32	0.15	0.50
33	0.15	0.50
34	0.15	0.50
35	0.15	0.50
36	0.15	0.50
37	0.15	0.50
38	0.15	0.50
39	0.15	0.50
40	0.15	0.50
41	0.15	0.50
42	0.15	0.50
43	0.15	0.50
44	0.15	0.50
45	0.15	0.50
46	0.15	0.50
47	0.15	0.50
48	0.15	0.50
49	0.15	0.50
50	0.15	0.50
51	0.15	0.50
52	0.15	0.50
53	0.15	0.50
54	0.15	0.50
55	0.15	0.50
56	0.12	0.46
57	0.12	0.46
58	0.12	0.46
59	0.12	0.46
60	0.12	0.46
61	0.12	0.46
62	0.12	0.46

63	0.12	0.46
64	0.12	0.46
65	0.01	0.02
66	0.01	0.02
67	0.01	0.02
68	0.01	0.02

Additional Data used in Figure 5:

Site selection

Excluded: Consent-based site screening process and scientific study

Design and Characterization

Estimated: Pre-conception design, preliminary design, final design

Excluded: Site characterization

Construction

Estimated: Surface facilities, subsurface facilities, equipment

Transportation and Operations

Estimated: Waste handling and emplacement, maintenance

Excluded: Disposal packaging and transportation

Closure

Estimated: Underground closure, sealing, backfilling, decontamination, site restoration

Monitoring

Estimated: 50 years monitoring after closure

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