Streamlining Plutonium Disposition

Addressing Challenges Within the Nuclear Weapons Complex

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Acknowledgements

About the Author

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List of Abbreviations

AEA	Atomic Energy Acts (of 1946 and 1954)
AEC	Atomic Energy Commission
CBO	Congressional Budget Office
CRENEL	Commission to Review the Effectiveness of the National Energy Laboratories
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
EM	Office of Environmental Management (within the Department of Energy)
EPA	Environmental Protection Agency
FAR	Federal Acquisition Regulation
FY	fiscal year
GAO	Government Accountability Office
HEU	Highly Enriched Uranium
HLW	High Level Waste
LEU	Low Enriched Uranium
LMC	Lockheed Martin Corporation
LMSI	Lockheed Martin Services Inc.
LNT	Linear No-threshold Theory
LWA	The Waste Isolation Pilot Plant Land Withdrawal Act
M&O	management and operations
MOX	Mixed-oxide fuel
MSA	Mission Support Alliance, LLC
mGy	miligray; a unit of measurement for radiation
mSv	milliSievert; unit of measurement for radiation
MT	metric ton (equivalent to approximately 1.10 ton)
NAS	National Academies of Science
NDAA	National Defense Appropriations Act

NNSA	National Nuclear Security Administration
NPR	Nuclear Posture Review (2018)
NPT	United Nations Treaty on the Non-Proliferation of Nuclear Weapons
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act (of 1982)
PMDA	Plutonium Management and Disposal Agreement
RCRA	Resource Conservation and Recovery Act
SC	Office of Science (within the Department of Energy)
SFS	The Spent Fuel Standard
SNM	Special Nuclear Material
SRS	Savannah River Site (in Aiken, South Carolina)
TRU	Transuranic
UNSCEAR	The United Nations Scientific Committee on the Effects of Atomic Radiation
WIPP	Waste Isolation Pilot Plant (in Carlsbad, New Mexico)

1. Executive Summary

The U.S. lacks a nuclear waste disposition program. Despite demonstrating technical competency, the country has yet to implement a policy, notably for its excess defense plutonium. The Department of Energy (DOE), the agency responsible for management of supporting activities for the nuclear weapons complex, historically has demonstrated management challenges. Unless the agency can overcome the challenges that exist in its current state, the U.S. will be unable to move forward with implementing any disposition policy.

The nuclear industry's aging infrastructure hinders the U.S. ability to remain competitive in the global sphere. Calls to modernize the U.S.' stockpile demand an update to the nuclear industry's infrastructure, some of which has not been updated since the end of WWII. Since much of the legislation was written and passed to match the rapid growth of the industry, the nature of the existing legal and regulatory framework is not conducive to swift action.

The DOE is disconnected from its disposition operations. The agency's over-reliance on contractors is hindering its cost performance and has resulted in "high-risk" management practices in offices overseeing nuclear waste disposition and storage.[1] Further, the DOE's lack of action on this issue has generated public mistrust. The public feels as if the DOE, and the federal government in general, is not equipped to handle nuclear waste management. In addition to this mistrust, the public fear of radiation has negatively impacted the perception of the nuclear industry, further complicating any actions the DOE takes. Given these concerns, the U.S. should implement the following recommendations:

(1) The DOE should strengthen its performance evaluation methods to better emphasize cost performance, as well as health and safety performance.
(2) In its draft of the "consent-based siting" process, the DOE should include more specific language to increase cooperation between state and local governments and to encourage mutual learning between the DOE and the communities involved.
(3) The DOE should pursue a *defense only* high-level waste (HLW) repository, as per the consent-based siting process. Successfully siting a repository will build the DOE's confidence, allow the agency to test their draft of the consent-based siting process, and result in another functioning repository.

These recommendations are a start towards implementing a nationwide disposition program. By implementing these recommendations, the DOE is addressing the concerns raised by the management of the disposition program; however, successfully implementing these recommendations, particularly recommendations (2) and (3), will also help rebuild the relationship between the DOE and the public.

[1] U.S. Government Accountability Office, "DEPARTMENT OF ENERGY: Performance Evaluations Could Better Assess Management and Operating Contractor Costs," 2019.

2. Key Conflicts

1. Aging Infrastructure Complicating Modernization Initiatives

It is inarguable that the industrial infrastructure of the nuclear weapons complex requires updating. If the U.S. does not update this infrastructure, the U.S. will be unable to address the goals presented by the NPR and will make facilities more vulnerable.

The current above-ground storage system is an adequate intermittent solution, but technological advances could put the material at risk. Nuclear materials are currently stored at sites around the country (Figure 1). According to a DOE report, in the event of a security breach or threat, an individual could make and detonate a makeshift explosive before the appropriate response reached the site.[2] In the past, there was a belief that "reactor grade" material could not be used to manufacture weapons; however, the nuclear community realized that "virtually any combination of plutonium isotopes… can be used to make a [an improvised] nuclear weapon."[3] The amount of Pu-239 to create a nuclear weapon is 4.7 kg.[4] If only supplied with reactor grade plutonium, an individual would just have to use *more* material than if they had used weapons-grade plutonium. While the U.S. has historically not had any problems with plutonium security, failure to upgrade current systems increases the vulnerability of materials in the near future. The U.S. currently spends $1 billion per year just on the physical security of defense-related SNM.[5] Centralizing storage will streamline efforts to secure the U.S.' nuclear material and promote cost-efficiency.

The U.S.' storage system does not adequately address the nature of plutonium. The long-lived nature of plutonium poses challenges in making sure that the material is not exposed to the surrounding environment. Some of the environmental concerns of disposal have been discussed in context to WIPP. WIPP is a desirable repository location because it sits on a salt bed, which inhibits the spread of radioactive particles and keeps out moisture. Despite this, there are still dangers associated with the site: "WIPP is surrounded by hundreds of oil and natural gas wells and is underlain by oil and natural gas and a large pressurized brine reservoir."[6]

Some have expressed interest in expanding WIPP to accommodate more waste, as opposed to opening a new repository. While this may be technically feasible, WIPP should not be expanded. WIPP has begun to fall victim to "mission creep," or the alteration of the mission over a period to meet the transient needs of the population. Expanding the operation of WIPP would stretch the abilities of the facility and the surrounding land. Additionally, since the LWA defines the maximum capacity of WIPP, this implies that WIPP should not be considered as a complete answer for the needs of the nuclear weapons complex. WIPP is a pilot facility; this location was never meant to be a permanent solution. The DOE should investigate other options for a repository.

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[2] Harold A. Feivson et al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation* (Cambridge, MA: The MIT Press, 2014).

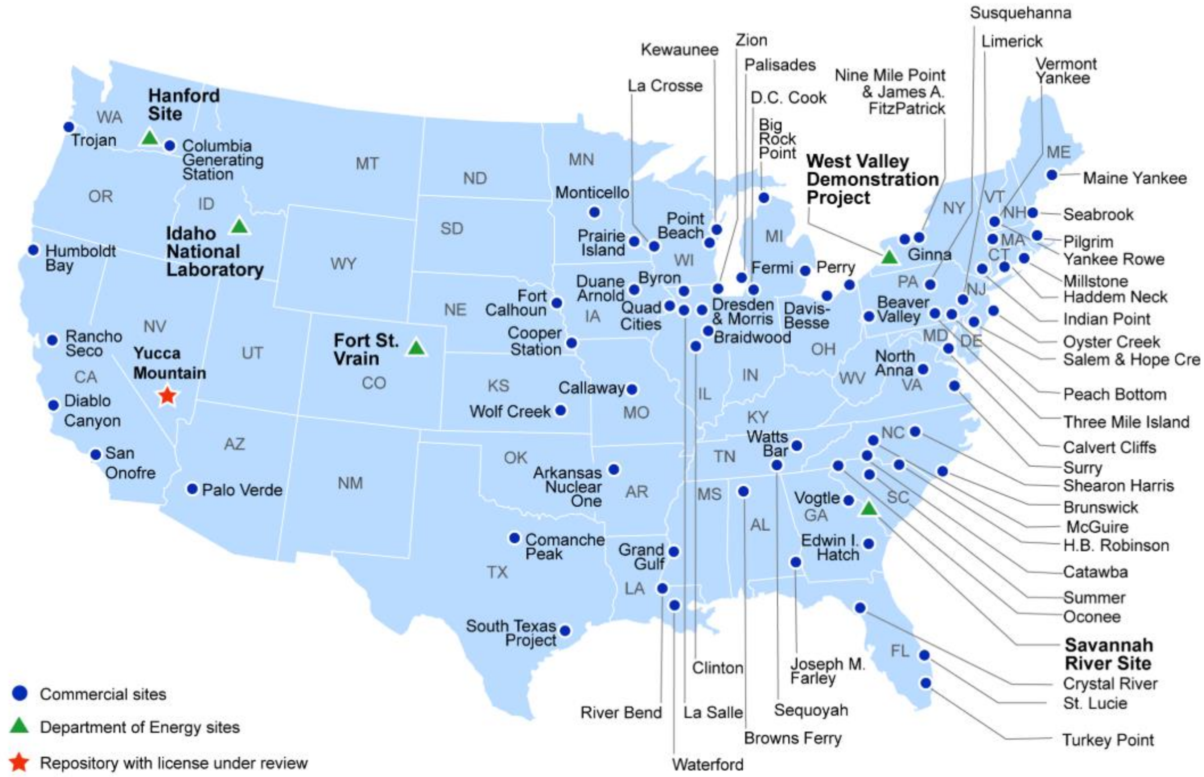
[3] U.S. Department of Energy, "Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives" (Washington, D.C., 1997).

[4] Feivson et al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation*.

[5] Feivson et al.

[6] Don Hancock, "Statement for Oversight Hearing on Examining America's Nuclear Waste Management, Storage, and the Need for Solutions," (2019).

Figure 1: Storage Sites for Defense-Related and Commercial High-Level Radioactive Waste and Spent Nuclear Fuel



Source: Department of Energy; GAO 17-174

2. *Demands of Current System Exceeding Its Capabilities*

Reactors in the U.S. annually produce 2,000 MT of waste.[7] Going forward, the amount of waste will only increase. Further, the growing needs of the weapons complex and the anticipated increase in pit production necessitates a new repository. The anticipated growth in the nuclear industry is also seen as a reason to expand WIPP; however, this solution favors expediency and should the need for another repository should not be ignored. The current legal and regulatory framework makes it such that repository siting is a political issue. Unlike defense spending, repository siting is a highly partisan issue.

The "intellectual" infrastructure of the nuclear industry is aging, much like its industrial infrastructure. The nuclear energy and weapons industries are unique in that many of its leading experts have lived to see several changes in legislation and public opinion in real time. The amount of experience is indispensable; however, more people are leaving the industry than there are entering it. In the past few years, interest in the nuclear industry has declined. The anticipated increase in weapons production and construction of new reactors calls for smart people to enter the industry. Without a steady stream of qualified and motivated individuals, the industry leaves itself vulnerable to more accidents caused by lack of experience, such as Chernobyl.

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[7] U.S. Government Accountability Office, "Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste," 2017.

Increasing the demand for qualified and willing individuals to enter the industry will not independently cause a dramatic increase in popularity of nuclear jobs. Unlike the generation who entered in the 1960's and 1970's, people entering the workforce today were born into a far more radiophobic society. The perception of the nuclear industry amongst the general public will, until addressed in a sweeping manner, hinder the industry's ability to progress at the necessary rate. The disconnect between the DOE and its contractors not only takes away from overall efficiency, but also further encourages maintenance of the status quo.

3. DOE Disengagement Impairing Cost Performance

Thorough analysis of DOE-contractor relationships shows a power imbalance that favors the contractors. Given the scope of the contracts and the massive network of subcontracts, it is plausible that the DOE plays little, if any role in operation and management of its facilities. The DOE does not understand its network of contractors and subcontractors and cannot gauge spending within this network.

One way for the DOE to better understand contractor activity is through performance evaluations. Each DOE office conducts performance evaluations differently. Each FY, contractors can earn a "fee" based on their performance. At the beginning of each FY, criteria are determined in the Performance Evaluation Management Plan (PEMP). The EM, the office that manages disposition initiatives, uses site-specific criteria. At WIPP, criteria are either considered "subjective" or "objective." Subjective criteria encompasses metrics that are not quantified: cost effectiveness, adherence to regulations, mission performance, and management performance are some examples of subjective criteria. Meeting subjective criteria accounts for 25% of the possible award for the FY. Conversely, objective criteria include things such as goals for processing rates or emission levels. Objective criteria, or "Performance Based Incentives" (PBI) account for 75% of the possible award. [8]

Theoretically, this system is useful because the missions of facilities differ drastically. Emphasis on the technical requirements of each contract is not unreasonable; DOE contract structure for its waste management focuses on "the finished product," rather than the process. The evaluations provide little information on cost, health, and safety performance. One major goal of the performance evaluations is to assess how the contractors performed with respect to cost, and the lack of criteria focusing on this goal cripples the agency's ability to make an informed decision on their contractors' performance.

Despite these intentions, the Government Accountability Office (GAO) found that the Office of Environmental Management's (EM) performance evaluation methods are inadequate. Performance evaluations almost always positively evaluate contractors, except for major security or safety incidents at the facilities (Appendix 2). Further, the current focus on objective criteria is diminishes the importance of the subjective criteria. Within subjective criteria includes "cost control" and health and safety performance.[9] Underemphasizing these criteria hurts the employees at these facilities: an article

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[8] U.S. Department of Energy, "Performance Evaluation and Measurement Plan," 2018.

[9] U.S. Department of Energy.

from the *American Journal of Public Health* found that the number of workplace injuries and accidents was directly correlated with cost overruns.[10]

Going forward, assuming that the DOE does not overhaul its operations structure, the agency will need to gain more clarity on its contractors and spending. Making more efforts to understand how contractors are operating will make it easier for the DOE to identify sources of conflict and resolve them more quickly. Further implementation of dilute and dispose will cost a significant amount of money upfront for construction, contracting, and other materials. One of the only ways to save money without altering the current managerial structure is to set more stringent standards with its contractors and subcontractors. Otherwise, the DOE will become a major taxpayer liability.

4. *DOE Inaction Allowing for General Mistrust*

The lack of action from the DOE makes the public, and states, wary. The DOE is not entirely to blame: the complexity of the current legal and regulatory framework, contractor-subcontractor network, and DOE-state relationships makes any action difficult. Nuclear energy and weapons policy is indicative of how these industries evolved. The industry's early, rapid development resulted in a system that can only be described as a big puzzle. Currently, the missions of sites such as WIPP and Yucca Mountain are currently written into federal law. In order to repurpose or alter the missions of these facilities, amendments to the respective pieces of legislation would have to go through the traditional legislative process.

Challenges are also exacerbated by the current DOE-state relationships. The channels of communication between the DOE and the states has deteriorated over time. As put by the Blue Ribbon Commission:[11]

> "Trust and confidence in the federal government's basic commitment and competence to deliver on its waste management obligations have eroded… Restoring that trust and confidence must be the government's first priority and is essential for getting all aspects of the nation's nuclear waste program back on track."

Since the DOE has not kept many of its promises with removing material form sites around the country, such as in South Carolina, the agency will face difficulty in convincing states to host a repository. In order to move forward with the dilute and dispose policy, the DOE must mend its relationships with state governments, or decide to act in spite of the opinions. A number of aspects of the siting process are ambiguous and the DOE's promises to better define them have fallen through.

The legacy of the Yucca Mountain project is holding the DOE back. Though Yucca Mountain was primarily not a defense-related project, the state of Nevada, and other states around the country, remember Yucca Mountain as a prime example of bad action on part of the federal government. Failure to adequately address the problems raised by Yucca Mountain will impair the government's ability to site repositories and storage sites in the future.

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[10] Michael Gochfeld and Sandra Mohr, "Protecting Contract Workers: Case Study of the US Department of Energy's Nuclear and Chemical Waste Management," *American Journal of Public Health* 97, no. 9 (2007): 1607–13, https://doi.org/10.2105/AJPH.2006.108795.

[11] Blue Ribbon Commsion on America's Nuclear Future, "Report to the Secretary of Energy" (Washington, D.C., 2012).

3. Recommendations

These recommendations focus on two technical issues: improving cost, safety, and health performance, and bettering the siting process for future projects. In addition to addressing these technical-leaning issues, these recommendations also seek to mitigate the growing amounts of mistrust directed towards the DOE.

One of the largest factors detracting from implementing these recommendations is cost. Nuclear and nuclear-adjacent activities are expensive. Projects can run into tens of billions of dollars, and recent projects such as MOX and Yucca Mountain have had disappointing results. Despite this, the U.S. has frequently poured money into the nuclear industry. Currently, defense-related nuclear spending will likely have less problems getting passed because of renewed interest in the nuclear weapons complex. In conclusion, spending on issues *not* related to defense will have to be more cognizant of spending than non-defense activities, due to the availability of funds.

Due to the nature of the cost of nuclear activities, cost will not be used to evaluate the recommendations. Additionally, DOE cost models have historically been unreliable.[12] Especially in the case of the MOX project, the DOE has been known to severely underestimate the costs of these projects. Any recommendations that are implemented will cost a significant amount to taxpayers; however, these costs are outweighed by the security and environmental risks faced if no action is taken.

[12] U.S. Government Accountability Office, "Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste."

1. Strengthen Performance Evaluations Within the EM

The EM should develop a standard PEMP structure and methodology where:

- The goals and objectives of criteria are well-defined
- Safety, health and cost performance are prioritized
- Evaluation process is well-defined

Currently, the goals and objectives within those goals are defined in the EM's PEMPs; however, safety, health, and cost performance are not emphasized, especially at WIPP. Currently, cost, safety, and health performance are under subjective criteria, which only account for 25% of the possible fee awarded. In a standardized evaluation method that the EM could implement, health, safety, and cost performance should account for a greater portion of the fee awarded. Additionally, objective criteria should also account for less than it currently does.

As part of this overall change, the EM should also individually weight the objectives listed under each overarching goal. Weighting each of the objectives will make the evaluation process more transparent. This way, it will be easier to see what specific things sites need to improve upon. Without weighting each objective, evaluation committees do not have to analyze the actions of the contractors as closely. By doing this, contractors will also have to submit more data relevant to assessing cost performance, which could affect contractor bookkeeping and spending behavior.

a. Strengths and Weaknesses

Implementing stronger performance evaluation methods would help the DOE understand its contractors' activities and better assess their cost performance. Having a greater understanding of these activities would contribute to the goals outlined by the GAO to take the EM off the High-Risk List. Further, increasing transparency makes the DOE more trustworthy.

Using performance evaluations to affect positive change is an incomplete approach. The issues outlined in Section 3.4 are not going to be solved by altering the performance evaluations; however, the performance evaluations as they currently exist are flawed and should be changed in a way where they affect positive change.

2. *Strengthen its Draft of the "Consent-Based" Siting Process*

The DOE should include more specific language to define the involvement of state governments and focus on educating communities on science and safety topics. In the draft, the DOE defines "community" as "the broad and inclusive participation from all of these groups and not limited to the local community."[13] Step 4 of the process, which includes filing a grant application, states the following:[14]

> "Communities respond to the funding opportunity notice indicating an initial interest in learning more about consenting to host an interim storage facility or repository. Briefings, meetings, information materials, and opportunities for open discussion are made available to communities that express interest. Communities submit grant applications."

At this step of the process, there should be extensive conversations not only between the implementing organization and the local community, but the local community and the state government. These interactions should be well-publicized. These conversations should include communicating the local benefits of siting to the state governments. The benefits of siting a repository are better realized with proximity, and legislators and representatives at the state level who are not from the area will not be able to understand without conversation.

During this step of the process, and while evaluating grant applications, the implementing organization should also make stronger efforts to inform the community of the disposition technology and communicate how this technology assures the most amount of safety. Though the type of facility is not determined until later in the process, the community should have full confidence in the technology's ability to keep them safe. The members of the community should also have a knowledge of how the technology works, not only for their own benefit, but also to prevent misinforming others in the process.

a. Strengths and Weaknesses

General pursuit of a consent-based siting process will help begin to mend the DOE's public image. More specifically, defining the role of the state level governments will ease points of tension that the DOE previously experienced in the siting process. Getting the states and local governments to reach an understanding, or something close to an understanding, will prevent the siting process from getting "stuck" in the same way that the Yucca Mountain project did. Increasing transparency in the decision-making process will also assure the public that their concerns are being addressed. Having discussions within the community will not only address any misunderstandings but will also help the greater community identify what some of its concerns are with respect to economics, overall community well-being, and environmental justice.

This process will also be clarified by founding major decisions on scientific information. Making the decision to site a repository, or not site a repository, within a community based on scientific fact is more durable reasoning than citing short term political or economic gain. Communicating this information in an approachable way will be difficult.

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[13] U.S. Department of Energy, "Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste," 2017.

[14] U.S. Department of Energy.

3. Pursue a Separate, Defense HLW Repository

The U.S. should also seek to open a separate defense HLW repository, as per the draft consent-based siting process. Most defense HLW is either excess plutonium, or byproducts from the production process of plutonium pits. The implementing organization for a defense-only repository would be the DOE. This means that the DOE would initiate the siting process, engage with communities, and evaluate grant applications. The U.S. will need to open multiple repositories in order to account for the increased activity across the nuclear industry, but starting with defense waste will be easier because of support for defense activities and the nature of defense HLW.

a. Strengths and Weaknesses

A defense-only repository is also likely to gain more support because of the support for defense-related activities. Current nuclear posture is conducive to supporting plans for defense infrastructure. The current nuclear modernization plan does not include spending on disposal of defense-related waste. Despite this, the plan could be altered by convincing Congress that this facility was necessary. The NDAA could be amended in the future in order to accommodate plans for siting a defense-only repository.

A defense HLW repository would likely be easier to site and garner more support than a co-mingled repository, such as Yucca Mountain. Since defense HLW is less radioactive than commercial HLW, communities may be more receptive to hosting a permanent repository. In the early stages of informing communities, distinguishing between different types of waste will help alleviate some of the fears that they hold.

While siting and constructing a separate repository is more expensive than doing the same for one co-mingled repository, it is likely the more time-efficient choice. The reality is that the U.S. needs to dispose of its nuclear waste as soon as possible. Even though defense waste only accounts for a small portion of the total amount of waste in the U.S., successfully siting and starting construction on a second repository in the U.S. would bolster public opinion of the DOE.

4. Introduction

The management of excess defense plutonium in the nuclear weapons complex has presented formidable challenges to the U.S. Impending pursuit of "dilute and dispose" as the U.S.' preferred plutonium disposition method is not hindered by technical incompetence, but the conduct exhibited by the DOE. As the global nuclear weapons complex continues to develop, the U.S. must be ready to adapt; however, we cannot hope to succeed without first addressing existing issues within existing legislation and management practices.

1. Technical Challenges Associated With Disposition

a. Defense-Related Waste

Defense-related waste is mostly highly-enriched uranium (HEU) or plutonium. Relative to other classifications of nuclear waste, defense waste is long-lived and emits lower levels of radiation. Excess plutonium is considered high level waste (HLW). In the Nuclear Waste Policy Act of 1982 (NWPA) and the Atomic Energy Acts of 1946 and 1954 (AEA), high level waste is defined as:[15]

> a) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and
>
> b) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation.

Despite the fact that defense waste, even defense HLW, emits lower levels of radiation than other types of radioactive waste, defense HLW "requires permanent isolation" in a geological repository. Thus, excess plutonium must be classified as HLW.

HEU and plutonium are utilized in weapons because they can sustain nuclear chain reactions. There are multiple isotopes, atoms of the same element that differ in the number of neutrons, of uranium and plutonium. Isotopes are identified by the nucleon number, which is the number of protons *plus* the number of neutrons in the atom. Fissile isotopes, which have odd nucleon numbers, are what allow the necessary reactions to occur. Some commonly referenced fissile isotopes are Pu-239, U-235, and Pu-241. Further, isotopic composition is used to classify material based on use:

Table 1: Weapons vs. Reactor Grade Pu[16]

TYPE	COMPOSITION	ORIGIN	USE
Weapons-grade	Pu-239 with less than 8% Pu-240	From military 'production' reactors	Nuclear weapons, or recycled as a MOX ingredient
Reactor-grade (from high-burnup fuel)	55-70% Pu-239; more than 19% Pu-240 (typically about 30-35% non-fissile Pu)	Comprises ~ 1% of used fuel from normal operation of civil nuclear reactors	As an ingredient of MOX fuel

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[15] Frank T Brogan, "Federal Register," *Federal Register*, 2011, http://content.ebscohost.com.library3.webster.edu/ContentServer.asp?T=P&P=AN&K=62672140&S=R&D=a9h&EbscoContent=dGJyMNHX8kSeqLM4xNvgOLCmr0qep7RSr6q4TLSWxWXS&ContentCustomer=dGJyMPGut1G1qLdKuePfgeyx44Dt6fIA%5Cnhttp://library3.webster.edu/login?url=http://se.

[16] "Plutonium," World Nuclear Association, 2018, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/plutonium.aspx.

The technical hurdles presented by plutonium disposition are significantly higher than those of HEU. The disposition of HEU is straightforward: the HEU is simply blended with low enriched uranium (LEU) or naturally occurring uranium. This fuel can then be used in civilian reactors around the country, whereas plutonium cannot be used in civilian reactors. Reprocessing plutonium in a similar manner to produce mixed oxide fuel (MOX), is more technically complicated and more expensive.

The longevity and processing requirements of plutonium pits pose additional challenges. For radioactive materials, the half-life refers to how long it takes for it to lose half of its radioactivity. The half-life of Pu-239, the most common isotope in pits, is 24,000 years.[17] Simply put, it is difficult to develop a disposition plan for a material that will outlive society as it exists today. This fact puts strain on future industrial and intellectual infrastructure to maintain designs that are put in place in the near term. Plutonium pits also require a disassembly process: they must be disassembled to a certain extent so that they can be stored safely. While the U.S. historically has not had issues with plutonium security during the disassembly process, mass disassembly may intensify security risks.

While these are formidable challenges, they are not impossible to manage. There are several qualities to consider, but a successful disposition method would:

- Be cost-effective
- Include burial in a deep geological repository
- Be technologically feasible

Anything involving nuclear materials is expensive, so minimizing costs is crucial when considering options for disposal. Additionally, burial in a deep geological repository addresses the security and environmental concerns associated with long-term disposition. Through extensive analysis of various alternatives and some trial-and-error, the DOE has largely settled on using a method dubbed “dilute and dispose” to manage the U.S.’ excess defense-related plutonium.

b. Dilute and Dispose

“Dilute and dispose” is a method already employed by the DOE at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, NM. WIPP predominately accepts non-hazardous waste contaminated by uranium or plutonium, or transuranic (TRU) waste. [18] Before getting sent to a facility such as WIPP, the material is altered in such a way that it is difficult to separate out the radioactive material. This new mixture is then placed in a canister, which is buried in a geological repository.

While WIPP itself has faced issues in its history, the relative success of the facility proves that this is a viable alternative. While this is currently the only repository in the United States, the plans for WIPP could be used to aid a siting body in choosing the location for a new facility. Implementation of dilution and disposal is also the most cost-effective measure of the alternatives previously investigated by the DOE: the total life-cycle cost of implementing this method would be $8.78 billion (Appendix 1).[19]

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[17] “Plutonium.”

[18] The technical definition of TRU Waste, as given by the Savannah River Site in SC: “waste contaminated with alpha-emitting radioisotopes with an atomic number greater than that of uranium (92), a half-life greater than 20 years, and a concentration level less than 100 nanocuries per gram.”

[19] U.S. Department of Energy, “Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options,” 2014.

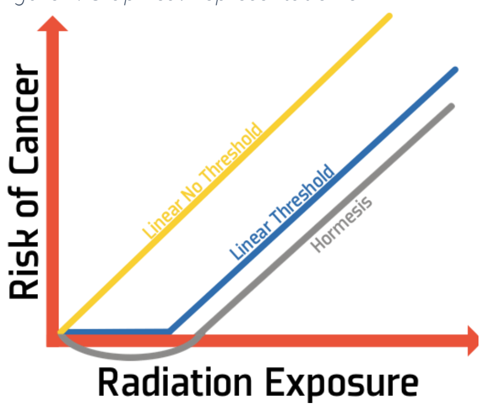
5. Background

1. Public Perception of Nuclear Technology

Apart from "nuclear counties" where the population is likely to be more sympathetic towards the nuclear complex, the general public has a negative impression of the nuclear industry. Radiophobia, the fear of ionizing radiation, is ever present in society. Internalized radiophobia rooted itself in American culture with the dropping of the atomic bombs in 1945 in Hiroshima and Nagasaki. Widespread fear emerged from the unknown consequences of radiation exposure, and the anti-nuke movement that followed the war became the precursor to modern environmentalist movements.

Radiophobic sentiment is still strong, partially due to misinformation. Much of the anti-nuclear movement is fueled by fossil fuel interest groups, resulting in legislation that is inherently anti-nuclear, maintaining the popularity of fossil fuel. These groups advocate for the idea that nuclear technology is dangerous and a public health hazard. Despite this, fossil fuel is not a radiation-free energy source: "Overall, coal-powered plants pose over 400 times the health hazard of radioactive emission from nuclear plants of the same power."[20] The commonality of fossil fuel energy in the U.S. desensitizes most people to the dangers associated with it.

Figure 2: Graphical Representation of LNT



Source: https://dialitdown.org/radiation-and-cancer/

Further, policies in most Western countries are informed by the Linear No-Threshold Theory (LNT). This widely referenced theory states the following:[21]

1. *Any* dose of radiation carries a health risk
2. Risk is linear with the dose (Fig. 2, yellow line)
3. Risk is independent of the dose-rate

LNT was first developed to explain the numerous deaths after Chernobyl. LNT still guides some scientists; however, the theory is not widely accepted and considered "controversial at best."[22] A survey by the National Institutes of Health (NIH) found that only 12% of scientists at U.S. National Labs agreed that LNT was the most appropriate Radiation Exposure-Response model for cancer.[23] Even given its uncertain status, LNT informs the 1 mSv $year^{-1}$ exposure limit in the United States. Despite reliance on this model, there have been studies that show that extremely small doses of radiation cause *decreases* in the number of cancer cases in the studied population.

a. Chernobyl and Fukushima: Case Studies in the Effects of Radiation Exposure

Experts often use Chernobyl and Fukushima as case studies for investigating the implications of nuclear incidents on a population. There is no doubt that these events have a negative impact on

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[20] Michael Myslobodsky, "The Origin of Radiophobias," *Perspectives in Biology and Medicine* 44, no. 4 (2019): 543–55, https://doi.org/10.1353/pbm.2001/0071.

[21] Myslobodsky.

[22] Myslobodsky.

[23] John J. Cardarelli II and Brant A. Ulsh, "It Is Time to Move Beyond the Linear No-Threshold Theory for Low-Dose Radiation Protection," *Dose-Response: An International Journal*, no. September (2018): 1–24, https://doi.org/10.1177/1559325818779651.

the public's perception of nuclear power. The 1986 Chernobyl accident was the result of a flawed reactor design and inadequately trained employees. While attempting to perform a test during a routine shutdown, the workers killed the automatic shutdown mechanisms. A flaw in the control rod design also caused a power surge when the rods were inserted into the reactor. The combination of failing backup cooling systems, the inpouring of cooling water, and pressure buildup caused a steam explosion. A few seconds later, a second explosion also occurred.

Unlike Chernobyl, the Fukushima Daiichi accident was not the result of design flaws or inexperienced personnel. In March 2011, an earthquake hit Japan, which caused a tsunami that hit 30 to 45 minutes later. The reactors did not sustain damage from the earthquakes, but from the tsunami: the seawall around the Fukushima Daiichi plant was only 5 meters tall, while the waves reached heights of 15 meters.[24] The seawater submerged the electrical systems, cutting off access to power to maintain the cooling systems. The backup never kicked in, causing the meltdown.

The communities affected by Chernobyl and Fukushima faced numerous health effects. Initially, it was unclear how many of the deaths as a result of Chernobyl were attributed to radiation exposure. As research was conducted, the scientific community found that radiation exposure was not as harmful as the public believed. In fact, the health effects were statistically inconsequential: studies following Chernobyl found that overall, radiation exposure presented a risk rate of approximately 0.0672% of premature death.[25] Risk of premature death does not exclude the presence of other health complications. The National Academies of Sciences, Engineering, and Medicine reported that "radiation-exposed populations such as the survivors of the atomic bombings in Hiroshima and Nagasaki have shown significant increases in cancer risk at high and moderate doses and at doses as low as the range from 0-100 milligray (mGy),"[26] Given these facts, it is clear that radiation exposure does pose risks, and safety should be prioritized in designing and siting facilities.

The other health problems faced by the population after Chernobyl were likely attributed to psychosocial factors. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) said that "many other health problems have been noted in the populations that are not related to radiation exposure."[27] Following Chernobyl, the rate of depression *doubled,* and the presence of suicidal thinking and alcoholism dramatically increased.[28] Similarly, the Fukushima accident caused "'severe psychological distress in the residents from evacuation zones' with effects including 'post-traumatic stress response, chronic anxiety and guilt, ambiguous loss,"[29] The effects of

[24] American Nuclear Society Special Committee on Fukushima, "Fukushima Daiichi: ANS Committee Report," 2012.
[25] David Ropeik, "The Dangers of Radiophobia," *Bulletin of the Atomic Scientists* 72, no. 5 (2016): 311–17, https://doi.org/10.1080/00963402.2016.1216670.
[26] National Academies of Science, Engineering, and Medicine, *Long-Term Health Monitoring of Populations Following a Nuclear or Radiological Incident in the United States: Proceedings of a Workshop* (Washington, D.C.: National Academies Press, 2019), https://doi.org/https://doi.org/10.17226/25443.
[27] World Nuclear Association, "Chernobyl Accident 1986," 2019, http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Chernobyl-Accident/#.Ul8K_hDA3z8.
[28] Ropeik, "The Dangers of Radiophobia."
[29] Ropeik.

fear are not limited to mental health: after Fukushima, there was an increase in the prevalence of hypertension, as well as an increased proportion of people who were overweight.[30]

The psychosocial factors are objectively detrimental to the state of the population; however, experts have not been able to effectively measure the economic impact of psychosocial effects of radiation. Further, regulatory bodies rarely assess these consequences when drafting regulation. Going forward, they must be considered in tandem with the impacts of radiation itself, even if they are not perfectly quantified or evaluated. As such, the DOE should not discount the effect of radiophobia when considering their actions regarding the nuclear complex, especially in siting nuclear facilities.

b. Public Opinion and Repository Siting

Securing local support for a repository or storage facility is not as difficult as gaining support at the state or national level. People who live in the areas near nuclear sites are able to realize the benefits of placing a facility there easier than someone who lives farther away. Part of this problem is due to lack of information; however, education does not completely solve it. Further, public mistrust of the government, and specifically the DOE, hinder the federal government's ability to gain support for projects. During public engagement sessions, the DOE found that there was a common feeling of mistrust towards the DOE. As one participant noted:[31]

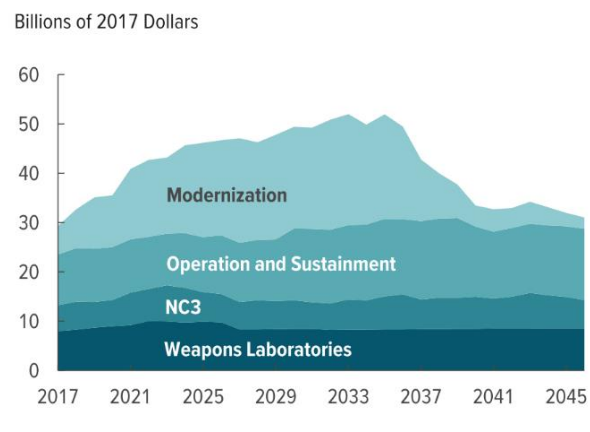
> "…if there is to be any process that is to be successful in achieving consent, it has to be a process that earns consent. It can't be consent on paper, even on brightly covered paper with lots of markers on it. And how do you get to that? Well, it's going to take time, and one might argue with DOE's history that it's going to be hard."

These sentiments should not be diminished by the DOE as they progress with disposition plans. As further proved by the DOE's feedback during public engagement sessions, the DOE must make extra efforts to build trust again with the public.

2. U.S. Nuclear Posture

Despite the pervasive fear of nuclear technology amongst the general public, the most recent Nuclear Posture Review (NPR) exhibits willingness to increase investment in the nuclear weapons complex. The NPR is a document that is published once per administration, detailing the specific goals and plans for the U.S.' nuclear stockpile. The Trump Administration's NPR articulates a clear desire to reassert the U.S.' dominance amongst nuclear weapons states in light of rising hostility on the global stage. The Review expands on desires to update a range of

Figure 3: Costs of Nuclear Forces Under the 2017 Plan, 2017-2046



Source: Congressional Budget Office, using data from the Department of Defense and the Department of Energy.

NC3 = Nuclear command, control, communications, and early-warning systems.

[30] Ropeik.

[31] U.S. Department of Energy, "Designing a Consent-Based Siting Process Summary of Public Input," 2016.

different weapons, proposes to increase production capabilities, and expresses concerns with past policies.

These concerns have largely been addressed by the nuclear modernization plan proposed by the Congressional Budget Office (CBO). In their 2017 report, *Approaches for Managing the Costs of U.S. Nuclear Forces, 2017-2046,* the CBO proposed a $1.24 trillion plan to update the U.S. nuclear capabilities, $216 billion of which would be dedicated for "labs and supporting activities" over the next 30 years.[32] While the CBO proposed a number of ways to distribute spending, the one discussed in the most detail assumes that plans will be implemented as soon as possible (Figure 3). In this scenario, spending is frontloaded, and peaks in the 2030's.

If implemented, stockpile maintenance would account for 6% of the defense budget, whereas it only accounts for 3% currently.[33] In a more recent report, the CBO projected the cost of DOE operations to be $106 billion from 2019-2028, $18 billion higher than their 2017 10-year estimate.[34] The 2019 number is a reflection of more concrete plans to increase plutonium pit production, which was one of the goals stated in the NPR.

The $216 billion estimate does not include non-proliferation and environmental management initiatives. Despite this fact, renewed interest in nuclear weapons development is still encouraging. Securing bipartisan support for nuclear and defense activities is not difficult. In June 2019, the Senate passed the 2020 National Defense Appropriations Act (NDAA) in an 86-8 vote that would secure funding for the nuclear modernization programs discussed in the NPR.[35] Many nuclear facilities date back to weapons development during the Cold War and WWII. With the intent to increase pit production and testing capabilities, the U.S. must invest in the supporting activities, such as disposition and storage sites. The DOE should capitalize on the pro-nuclear sentiment to its fullest capabilities.

3. *Legal, Political, and Regulatory Framework*

The responsibility of managing nuclear materials has changed hands several times. The AEA sought to establish "a program for Government control of the possession, use, and production of atomic energy and special nuclear material (SNM)."[36] The AEA of 1946 established the Atomic Energy Commission (AEC), a body that would oversee both the civilian use of nuclear technology and management of "special nuclear material" in weapons. In 1954, the AEC was dissolved, resulting in the organizational structure that is in place today. The Nuclear Regulatory Commission (NRC) oversees civilian uses of nuclear technology, while the DOE oversees defense-related uses of SNM. Civilian uses of nuclear predominately include reactors generating electricity, and radiological medical devices.

a. History of Plutonium Disposition Policy

Since the beginnings of the nuclear weapons development in the 1940's, the DOE has failed to decide on the U.S.' plutonium disposition policy (Figure 4). Previously, it was believed that if there was

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[32] Congressional Budget Office, "Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046," 2017, www.cbo.gov/publication/53211.

[33] Congressional Budget Office.

[34] Congressional Budget Office, "Projected Costs of U.S. Nuclear Forces , 2019 to 2028," 2019.

[35] Dan Leone, "Nuke-Backing NDAA Passes Senate in Landslide," *Exchange Monitor*, June 28, 2019.

[36] "Atomic Energy Act of 1954" (1954).

no clear policy, the rate of weapons production and the use of civilian reactors would decline. It was impossible to predict the rate of weapons production far into the future, so excess plutonium was stored in temporary, above ground facilities. The majority of the U.S.'s excess plutonium is still in these facilities.

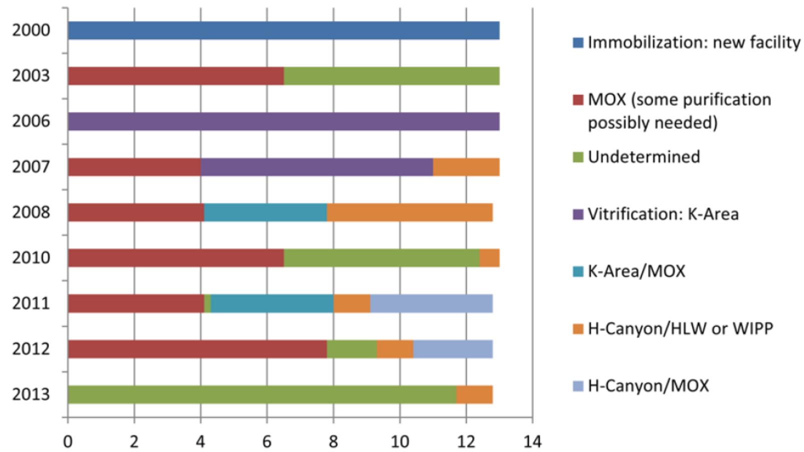
Congress first authorized shipments to WIPP in 1979, but the facility did not receive its first shipment until 1999. In 1979, the WIPP Land Withdrawal Act (LWA) gave the DOE total oversight of WIPP, with the exception that the shipping containers for the waste must be approved by the NRC. Further, the LWA also designated a limit for the amount of waste that could be disposed at WIPP. New Mexico, the host state, was given no regulatory power. After experiencing resistance from the NM government, Congress amended the LWA and gave the state the ability to define the types of waste shipped to WIPP.

Many of the U.S. decisions regarding plutonium disposition have also been impacted by the Plutonium Management and Disposition Agreement (PMDA). In 2000, the United States and Russia signed the PMDA. The purpose of the agreement lies in the name: the U.S. and Russia must pursue parallel efforts to dispose of 34 metric tons (MT) of plutonium from old Soviet warheads. Further, the PMDA states that it must be disposed of by reprocessing the old pits into MOX fuel to be used in civilian reactors. As part of the agreement, the U.S. would provide $400 million in financial assistance to Russia to complete the disposition. Because of pressure from Russia, and the text of the PMDA, the U.S. was moved to pursue the construction of a reprocessing facility.

Thus, in 2002, the DOE began the MOX project. In Article III of the PMDA, it says that the disposition method *must* be agreed upon by both the U.S. and Russia. This provision within the agreement prevented the U.S. from pursuing alternate options to dispose of the 34 MT designated in the agreement. Over its lengthy history, there were issues with mismanagement, materials security, and overspending. The project was ultimately shut down in October 2018 due to cost overruns. If seen to completion, the MOX facility would have allowed the U.S. to complete disposition of the 34 MT by 2043, the soonest finish line of all the options considered by the DOE.[37]

[37] U.S. Department of Energy, "Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives."

Figure 4: Disposition Method for 13 MT of Excess Pu



Horizontal Axis is mass of excess plutonium in metric tons (MT).

In the budget request for the FY 2019, National Nuclear Security Administration (NNSA), requested $59 million to "pursue the proven dilute and dispose technology," effectively declaring dilute and dispose the preferred disposition method.[38] The relative success of WIPP's operations is a strong indicator that "dilute and dispose" is a viable alternative for the foreseeable future.

b. Organizational Structure of the DOE

In the context of defense plutonium disposition, the DOE is both the regulator and the regulated. The dissolution of the AEC contained management of defense related SNM to the DOE. Thus, the DOE effectively self-imposes regulations on its facilities. Further, there is no independent oversight of DOE activities. Bodies such as the Government Accountability Office (GAO) or the Defense Nuc lear Facilities Safety Board (DNFSB) are limited to making suggestions and holding hearings about DOE activities. Additionally, the DNFSB only has oversight of buildings where *defense* activities are taking place, further narrowing the scope of the organizations' abilities. While these activities are useful for pointing out weaknesses in the DOE's practices, the DOE is not obligated to follow any of the recommendations posed by GAO reports or address any concerns brought about in DNFSB hearings.

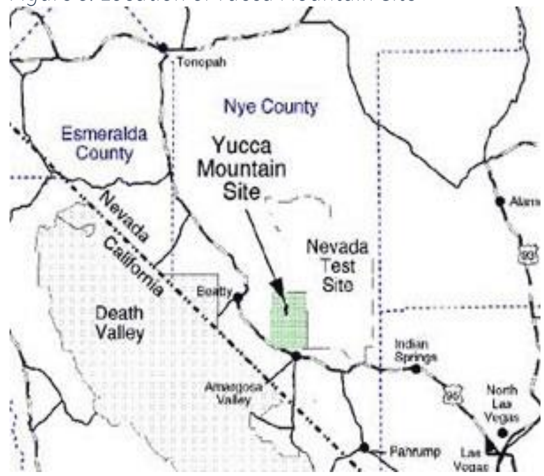
The only two agencies that can definitively start and stop DOE activities are the DOE itself, and the Environmental Protection Agency (EPA). DOE facilities must be licensed by obtaining a permit from the EPA: without the license, the facility cannot operate. In order to apply for a permit, the DOE must submit a report to the EPA and have conducted extensive safety and environmental assessments. Once the facility has been licensed, the EPA continues to monitor activity at the facility. The permits must be renewed every ten years.[39]

[38] U.S. Department of Energy, "Department of Energy FY 2019 Budget Request Fact Sheet," 2018, https://www.energy.gov/sites/prod/files/2018/02/f48/Energy Department FY 2019 Budget Fact Sheet.pdf%0Ahttp://energy.gov/fy-2017-department-energy-budget-request-fact-sheet.

[39] "Part 270 - EPA Administered Permit Programs: The Hazardous Waste Permit Program" (Code of Federal Regulations, title 40 (2012), 2012), https://www.govinfo.gov/content/pkg/CFR-2012-title40-vol28/xml/CFR-2012-title40-vol28-part270.xml#seqnum270.50.

The EPA is also responsible for enforcing the Resource Conservation and Recovery Act (RCRA). Licensing facilities is also done through RCRA. The EPA states the primary purpose of RCRA to be to give "EPA the authority to control hazardous waste from the 'cradle-to-grave.'"[40] Enforcement of RCRA is carried out at the state level. At WIPP, the New Mexico Environment Department enforces RCRA on behalf of the EPA. Delegation of RCRA enforcement gives states the ability "to control… treatment, storage, and disposal of hazardous waste."[41] By this sentiment, states have more control over the influx and types of waste that they receive, as opposed to it being controlled by the federal government.

Figure 5: Location of Yucca Mountain Site



Source: NRC Website

c. *Facility Siting*

Beginning a new project requires high levels of coordination from all levels of government. The need for a repository has been realized by the federal government for a number of years. Despite this, they have still struggled in successfully operating a repository, with the exception of WIPP. Repository siting is one of the most complicated issues that the industry faces. In 2012, the Blue Ribbon Commission suggested that the U.S. adopt a "consent-based process" for siting its facilities.[42] In other words, the federal government must get permission from the community in which the repository is placed in. The DOE has engaged the public in order to best define "consent-based" siting. The DOE has created a draft of the process, outlined in the 2017 report, *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste* (Appendix 3b). Since releasing the draft, the DOE has not published a final version, nor has the process been implemented by a federal agency. Other organizations and agencies have successfully used similar procedures for siting facilities, so the success of the DOE's draft is hopeful. Since the number of sites is few and far between, there is not a permanent siting body, or a set of definitive procedures for establishing the site of a new facility.

The first repository evaluated for siting in the U.S. was Yucca Mountain in Nevada (Figure 5). The NWPA stated that the U.S. should site a geological repository to store spent nuclear fuel (SNF) and HLW. The site was intended to be a co-mingled repository, storing SNF, civilian HLW, and defense HLW. The federal government conducted research on three sites in Nevada, Washington, and Texas. Originally, the U.S. wanted to pursue construction at all three sites, but after realizing their initial cost estimates severely underestimated the cost of construction, decided to only pursue Yucca Mountain.

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[40] U.S. Environmental Protection Agency, "Summary of the Resource Conservation and Recovery Act: 42 U.S.C. §6901 et Seq. (1976)," 2018, https://www.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act.
[41] U.S. Environmental Protection Agency.
[42] Blue Ribbon Commsion on America's Nuclear Future, "Report to the Secretary of Energy."

Nevada was not happy with the decision. In 1987 when Yucca was first picked, then Nevada Governor Kenny Guinn vetoed the decision, which was later overturned by a vote in Congress.[43] Nevada felt that they were politically weak compared to Washington and Texas. Further, the state of Nevada expressed concerns that the federal government favored expediency over safety in choosing Nevada. In addition to the state government, environmental groups and impassioned citizens also expressed extremely negative views on the Yucca Mountain facility.[44] Despite this backlash on the state level, Yucca Mountain gained large amounts of local support; however, this was not enough for the facility to succeed. In 2015, the Obama administration terminated funding to Yucca Mountain, and the site is currently abandoned. While the Bush administration filed for a license, the project was never able to license Yucca Mountain and thus never got to begin construction.

The siting at WIPP was handled very differently. From the outset, there was local level support, similar to Nevada; however, support from the state government came later. The state government was "willing to remain engaged" throughout the process, according to Sandia National Laboratory.[45] Despite its success, WIPP should be considered the exception, rather than the rule. Since the establishment of WIPP, the U.S. has failed to gain enough support from Nevada to get the permits approved. WIPP is always given as an example of successful "consent-based" siting, but the government has yet to define this process. Further, the politics were much more favorable in New Mexico than they were in Nevada, further helping the case of WIPP.

There is a clear disconnect between local and state level governments. According to some participants of a Bipartisan Policy Center Nuclear Waste Council regional meeting near WIPP, "politicians from bigger cities like Austin and Santa Fe often raised questions and concerns, but then failed to consistently appear at local meetings or work with local officials to address these concerns."[46] Behavior like this from state politicians is

4. *DOE Use of M&O Contracts*

The DOE's responsibilities are twofold: to oversee their contractors and subcontractors, and to provide funding for operations. DOE headquarters oversee operations, and the field offices are more responsible for facilitating day-to-day activities at specific sites. The DOE heavily depends on its contractors: in the FY 2016, the DOE spent nearly 90% of its appropriations on contracts.[47] The DOE has capitalized on contract-based work since the end of WWII to carry out its mission. In particular, the DOE utilizes management and operating (M&O) contracts.

[43] Eureka County Nevada - Nuclear Waste Office, "FAQ's: Frequently Asked Questions," YuccaMountain.org, 2015, https://www.yuccamountain.org/faq.htm#why_yucca.
[44] Matthew C. Nowlin, "PARTISANSHIP , INFORMATION , AND PUBLIC OPINION ABOUT YUCCA MOUNTAIN," in *International High Level Radioactive Waste Managment* (Charleston, SC, 2015), 226–31.
[45] Paul Shoemaker, "Siting , Developing , and Licensing of WIPP," 2015.
[46] B P C Nuclear and Waste Council, "Moving Forward with Consent-Based Siting for Nuclear Waste Facilities," no. September (2016).
[47] U.S. Government Accountability Office, "DEPARTMENT OF ENERGY CONTRACTING: Actions Needed to Strengthen Subcontract Oversight" (Washington, D.C., 2019).

Federal Acquisition Regulation (FAR) defines M&O contracts as "agreements under which the government contracts for the operation, maintenance, or support, on its behalf, of a government-owned or government-controlled research, development, special production, or testing establishment, wholly or principally devoted to one or more major programs of the contracting agency."[48] M&O contracts lend themselves to closer relationships between the DOE and its contractors; however, communication is limited. When operating under an M&O contract, the DOE is more concerned with the final product. In other words, the DOE will give the contractor a mission and will not scrutinize the process if the final product is good.

When the DOE wants to hire a contractor, the DOE will release a "Request for Proposal." Companies will then submit proposals and, according to USA.gov, evaluates them based on the following criteria:[49]

- Responsibility and responsiveness of the business
- How technically acceptable the proposal is
- References
- Pricing and terms of the proposal

The intention of M&O contracts was to outsource specialized skills; however, "Performance Evaluations" found that DOE contracts had "broad scopes of work that cover nearly all aspects of work at a site."[50] On the high end, 50% of contractors' total costs in the FY 2015 were attributed to managing facilities, grounds, infrastructure, and security.[51] The broadening scopes of work are likely the reason contractors hire sub-contractors to fulfill their contracts. Occasionally, sub-contractors will also hire sub-subcontractors.[52]

The GAO has two reports, "Actions Needed to Strengthen Subcontract Oversight" and "Performance Evaluations Could Better Assess Management and Operating Contractor Costs." These reports analyze sources of strain in DOE-contractor relationships. "Subcontract Oversight" highlighted weaknesses in the DOE's subcontract management practices, elaborated on the challenges in understanding the contractor-subcontractor relationships, and emphasized the difficulty in effectively analyzing them. The "Performance Evaluations" report mainly explained the nature of the DOE's use of M&O contracts and the ineffectiveness of annual performance evaluations. Both reports specifically criticized the EM[53] and National Nuclear Security Administration's (NNSA) contract management practices across the board, and specifically mentioned oversight of funds.

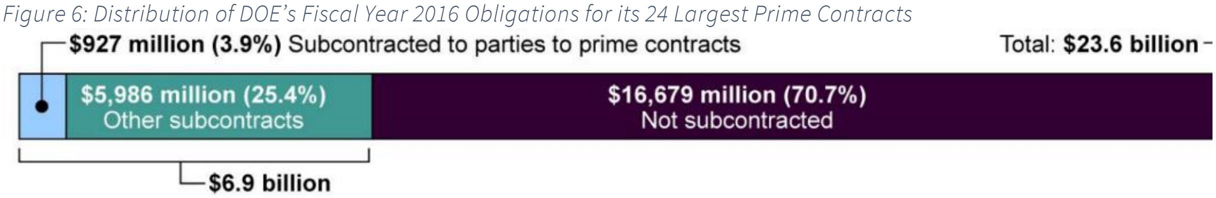
[48] Federal Acquisitions Regulation.
[49] "How to Become a Federal Government Contractor," USA.gov, n.d., https://www.usa.gov/become-government-contractor.
[50] U.S. Government Accountability Office, "DEPARTMENT OF ENERGY: Performance Evaluations Could Better Assess Management and Operating Contractor Costs."
[51] U.S. Government Accountability Office.
[52] Gochfeld and Mohr, "Protecting Contract Workers: Case Study of the US Department of Energy's Nuclear and Chemical Waste Management."
[53] Plutonium disposition activities (e.g. WIPP) operate under EM

a. Analysis of DOE Sub-Contractor Oversight Practices

Contract management for the NNSA and EM are on the GAO's "High-Risk List" for operations vulnerable to fraud, waste, abuse, and mismanagement.[54] The "Subcontract Oversight" report found that many of the parties to "prime contracts" were also subcontractors to parties to prime contracts. Further, "Subcontract Oversight" noted that the web of contracts and subcontracts was difficult to decipher, and it was often unclear who the parties to the prime contracts were. In the FY 2016, $927 million of the $6.9 billion spent on sub-contractors was for subcontracted parties who were already parties to prime contracts (Figure 6).

Sub-contractor audit practices are weak. The "Subcontract Oversight" report found that the DOE did not require all of its contractors to audit their subcontractors, forcing the DOE to eat "unallowable" subcontractor costs.[55] The consequences of weak auditing practices and the confusing relationships between contractors are exemplified in the case *United States vs. Mission Support Alliance, LLC (MSA).* The U.S. technically filed suits against MSA, Lockheed Martin Corporation (LMC), Lockheed Martin Services Inc. (LMSI), and Jorge Francisco Armijo, who is a VP of LMC. MSA is one of the parties to a multi-billion dollar contract for clean-up at the Hanford Site in Idaho. One of the owners of MSA, Lockheed Martin Integrated Technology, is a fully owned subsidiary of LMC.

Figure 6: Distribution of DOE's Fiscal Year 2016 Obligations for its 24 Largest Prime Contracts



Source: GAO analysis of Department of Energy (DOE) and contractor information. | GAO-19-107

In 2010, MSA noncompetitively awarded LMSI a $232 million subcontract.[56] The United States claims that MSA knowingly made false statements to the DOE about profits in the subcontract by reporting inflated rates. Additionally, LMC made payments totaling $1 million to MSA executives, including Jorge Francisco Armijo, to receive undue preferential treatment by MSA. Strengthening subcontractor management practices would allow the DOE to better understand the relationships between contractors and subcontractors, while also minimizing the possibility of other consequences.

b. Analysis of DOE Performance Evaluations & Cost Performance

The DOE's contract structure further leaves the agency vulnerable to fraud and abuse. The DOE utilizes "cost-plus-award-fee" contracts, otherwise known as cost reimbursement contracts. In cost reimbursement contracts, the value of the contract is not fixed at its signing; instead, the value is dependent on how much the contractor spends and is later reimbursed by the government. Cost-

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[54] U.S. Government Accountability Office, "DEPARTMENT OF ENERGY: Performance Evaluations Could Better Assess Management and Operating Contractor Costs."

[55] U.S. Government Accountability Office, "DEPARTMENT OF ENERGY CONTRACTING: Actions Needed to Strengthen Subcontract Oversight."

[56] U.S. Department of Justice, "United States Files False Claims Act Suit Against Mission Support Alliance LLC, Several Lockheed Affiliates, and Jorge Francisco Armijo for Inflated Information Technology Subcontract Costs" (Washington, D.C.: Office of Public Affairs, 2019), https://www.justice.gov/opa/pr/united-states-files-false-claims-act-suit-against-mission-support-alliance-llc-several.

reimbursement contracts impose more risk on the DOE, as opposed to a "fixed cost" model where the value is set at signing. Unlike fixed cost contracts where there is a maximum amount that the DOE is obligated to pay, the value of cost reimbursement contracts can increase indefinitely.

The DOE's performance evaluation methods are not standard across offices, and EM's practices are particularly relaxed. Annual performance evaluations allow the DOE to assess their contractors' cost-effectiveness and technical competency or ingenuity. The GAO report found that the DOE was highly unlikely to negatively rate contractor performance, with the exception of a major accident or incident at the facility. It is apparent that companies are awarded regardless of actual performance.

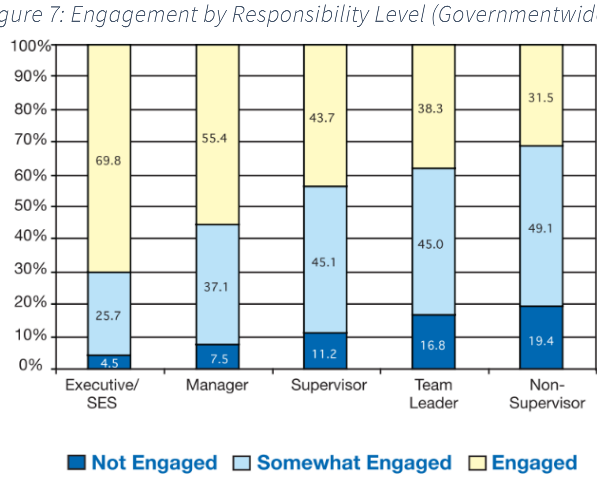
Other independent commissions and external groups have reported on contract management challenges; most notably, the 2014 Augustine-Miles Panel and the 2015 Commission to Review the Effectiveness of the National Energy Laboratories (CRENEL) focused on challenges specific to DOE contract management. The Augustine-Miles Panel looked at DOE-contractor relationships across different offices and found erosions of trust in many relationships. Before pursuing contracts for future disposition-related projects, there must be a solid relationship between the DOE and its contractors. Issues with contract management must be solved to ensure good cost performance and credibility within the contractor-DOE circle.

5. *Employee and State Relations*

a. Employee Engagement

Every year, federal agencies conduct the Federal Viewpoints Survey to gauge employee satisfaction and experience. In general, the DOE has higher percentages of positive responses than the governmentwide averages. The DOE ranks 10th in overall employee engagement governmentwide at 72%, where the average is 68%.[57] Relative to other agencies, the DOE is not a "bad" place to work. Despite this, only 47% responded positively to the question, "In my organization, senior leaders generate high levels of motivation and commitment in the workforce."[58] Executives show nearly 70% engagement, whereas non-supervisors show 31.5% (Figure 7). This disparity in engagement level indicates misunderstandings of the agency's true goals at lower levels of management. Conflicts between upper management and lower level employees resulting from these misunderstandings are avoidable and should be minimized through improved methods of communication.

Figure 7: Engagement by Responsibility Level (Governmentwide):



Source: *The Power of Federal Employee Engagement*

[57] United States Office of Personnel Management, "Federal Employee Viewpoint Survey Agency Management Report," 2018, U.S. Department of Energy.

[58] United States Office of Personnel Management.

b. DOE-State Relationships

The DOE's behavior has deteriorated its relationship with many states. South Carolina, the center of the failed MOX fuel reprocessing project, filed a $200 million suit against the DOE for failing to remove weapons-grade plutonium from the Savannah River Site (SRS) by the beginning of 2016. Federal law legally allows South Carolina to fine the DOE $1 million per day after January 1, 2016 that the DOE fails to remove the plutonium from SRS.[59] While the suit only covers missed fines from 2016-2017, South Carolina also claims that the DOE owes fines from 2018 and 2019. It should be noted that the relationship between South Carolina and the DOE is particularly intense, but suits against the DOE are all but uncommon. Settling suits requires dedication of time and money and furthers cost-inefficient behavior within the agency. In 2016, the total payout for lawsuits against the DOE neared $6 billion.[60] State relationships will be more important going forward; the consent-based siting process will not allow the DOE to move forward with planning for a new repository.

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[59] Dan Leone, "Settlement Talks Collapse in $200-Million Lawsuit over Savannah River Plutonium," *Exchange Monitor*, July 2019.

[60] Mark Fahey, "How the Department of Energy Became a Major Taxpayer Liability," *CNBC*, October 16, 2016, https://www.cnbc.com/2016/07/05/how-the-department-of-energy-became-a-major-taxpayer-liability.html.

6. Conclusions

These recommendations alone do not address all the challenges that exist with regards to this issue. In addition to the other challenges mentioned in this paper, there are a plethora of other circumstances that will affect the fate of nuclear disposition policy. One of the biggest challenges to nuclear activities is changes in administration. The nature of nuclear policies is that they take long periods of time to license and carry out, which is the opposite of how politics in the U.S. works. Going forward, it will be important for the nuclear industry to keep making short term changes to the existing system until it is possible to implement a plan that will outlast any one administration. This goal, while daunting, can be achieved through trust in the science and technology that these plans are based on.

7. Appendix

1. Rejection of Other Disposition Alternatives

The National Academy of Sciences (NAS) drafted a set of conditions that define the intrinsic properties of dispositioned plutonium, called the Spent Fuel Standard (SFS). "Intrinsic" properties include the isotopic composition, physical form, and chemical properties of the material. In addition to the intrinsic "barriers" that are defined by the SFS, there are engineered and geological barriers that further protect the dispositioned plutonium. The NAS views the SFS as a necessary condition that dispositioned plutonium should meet; however, since the NAS is not a regulatory body, dispositioned plutonium is not legally obligated to meet the SFS. In addition to meeting the SFS, the NAS suggest that engineered barriers be updated periodically to account for technological advances.

a. Alternatives Presented by the DOE

The DOE conducted an analysis of five "alternatives" to our current disposition policy:[61]

1. Irradiation of Pu in a LWR (MOX)
2. Irradiation of Pu in a "Fast Reactor"
3. Immobilization (i.e., vitrification)
4. Dilution of plutonium and disposal in a repository (e.g., WIPP)
5. Deep borehole disposal (a.k.a. "can-in-canister")

In 2014, the National Academy of Sciences (NAS) identified two viable disposition alternatives: MOX and vitrification. MOX is the same method that the U.S. attempted to adopt in 2002, but ultimately shut down. Vitrification, known also as "immobilization," is a method that turns liquid waste into a glass or a ceramic. The immobilized product is then stored, usually in a deep geologic repository. These options, in the view of the NAS, were superior to others because they ensured that the dispositioned plutonium met the SFS; however, meeting the SFS does not mean that that method is better than another.

The second option, irradiation of plutonium in a fast reactor, is an alternative that frequently gets discussed in tandem with MOX.

Dilution and disposal, the fourth option, is a method already employed by the DOE. The WIPP facility in New Mexico currently employs this tactic. Before getting sent to a facility such as WIPP, the waste is altered in such a way that it is nearly impossible to separate out the radioactive material. This new mixture is then placed in a canister, which is buried in a geological repository.

The final option, deep borehole disposal, is the alternative that has been investigated the least extensively. In this alternative, plutonium is directly disposed in canisters, which are then placed in a borehole 5,000 meters deep, occupying the bottom 2,000 meters of the hole.[62]

b. Rejection of the "Fast Reactor" and Deep Borehole Disposal

Amongst reactor alternatives, the "fast reactor" is advantageous for reasons its name suggests. This alternative would decrease the disposition time; however, this advantage rests on the assumption that the infrastructure is already in place to operate such a reactor. Relative to the options already

[61] U.S. Department of Energy, "Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options."
[62] U.S. Department of Energy.

considered, the initial capital required to build a new reactor is low: $9.42 billion. Despite this, the total life cycle cost of the "fast reactor" alternative is over $50 billion, nearly double that of the MOX or vitrification alternatives.[63] Additionally, because of the time required to build and license a new reactor, the dispositioning of the 34 MT of plutonium required by the PMDA would not be complete until 2075.

There are no good cost estimates of this method. This option is praised for its simplicity and ability to implement. If implemented, disposition could be completed as of 2051. As with all the other options, other than dilute and dispose, there is no infrastructure in place to proceed with deep borehole disposal.

c. Rejection of Vitrification and MOX

One of the main issues with vitrification is the cost of implementation: the total life cycle cost of vitrification is $28.65 billion, as estimated by the 2014 DOE study.[64][65] This is comparable to the total cost associated with the MOX project, and much greater than the other non-reactor alternatives presented in the DOE study. Additionally, the U.S. lacks the infrastructure necessary to support vitrification on a large scale. There are Cold-War Era facilities that could be repurposed to support this operation, but they would still require updating. In addition to the cost, the projected disposition completion time for vitrification is not competitive with other methods: the earliest disposition could be completed is 2060.[66]

The most pressing concern with pursuing MOX reprocessing is the economics: it would cost less to purchase uranium than to fabricate the same amount of MOX fuel."[67] There is no market for MOX fuel in the United States. Originally, there was a belief that we would run into a shortage of uranium, but we have found that to be untrue; there is enough uranium to sustain us for the foreseeable future. Since we realized that the global supply of uranium is higher than we initially thought, the cost of uranium has become considerably lower, making it a more competitive option.

The U.S. MOX project realized this fact very quickly: The main reason why the MOX project in the U.S. got shut down was because of cost overruns. In 2013, the estimated costs of the MOX project rose from $1 billion to $7.7 billion, not including the cost of reprocessing the plutonium.[68] A 2014 DOE study also projected new costs for the project. At the time of the study, it was projected that there were $6.46 billion in capital costs, and the total life cycle cost to-go estimate was $25.12 billion.[69] Simply put, the cost of implementing the MOX fuel cycle in the U.S. was too high.

Reprocessing plutonium as MOX fuel creates a plethora of security implications. To fully assess the value of MOX fuel, we should go back to its origins. Reprocessing technology was originally *only*

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[63] U.S. Department of Energy.

[64] The estimated costs provided by the 2014 DOE study were used in reference to the disposition of the plutonium required by the PMDA.

[65] U.S. Department of Energy, "Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options."

[66] U.S. Department of Energy.

[67] Feivson et al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation*.

[68] Feivson et al.

[69] U.S. Department of Energy, "Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options."

held by nuclear weapons states, as defined by the UN Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Most weapons states prevented the spread of this technology because many were concerned that the technology would aid the proliferation of nuclear weapons. Originally, the United Kingdom and France acquired reprocessing technology for this exact reason.[70]

The security concerns associated with reprocessing were further highlighted over the course of the U.S. MOX project. In his 2014 white paper entitled “Excess Plutonium Disposition: The Failure of MOX and the Promise of Its Alternatives,” Dr. Ed Lyman brings up the point that changes to NRC regulation would relax security standards for the storage, transportation, and use of MOX fuel.[71] These changes, enacted in order to make the project more profitable, would make fuel reprocessing more likely to be exploited for nefarious uses.

A final “advantage” that MOX presents is that it does not require storage in a deep geological repository; however, this belief is false. MOX fuel cannot be reprocessed an infinite number of times and must eventually be moved to permanent storage. The most feasible type of permanent storage of nuclear waste is a deep geological repository, such as the WIPP facility. No matter the technology ultimately used, the need for a deep geological repository will not disappear. Given this information, it does not make sense to pursue an option like MOX that has a high overhead cost.

[70] Arjun Makhijani, “The Mythology and Messy Reality of Nuclear Fuel Reprocessing” (Takoma Park, 2010).
[71] Edwin S Lyman, “Excess Plutonium Disposition: The Failure of MOX and the Promise of Its Alternatives,” 2014.

2. More Information on Office of Environmental Management Facilities' Performance Evaluations

Table 2: Percentages of Available Award and Incentive Fees Earned by the Office of Environmental Management's (EM) Management and Operating Contractors Each Fiscal Year, 2006 through 2016[72]

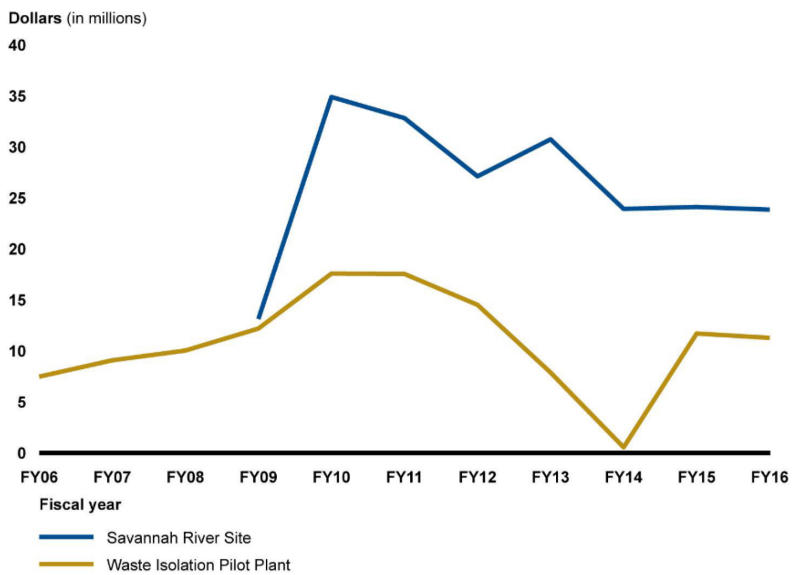
All numbers are percentages

Contract rating site	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Savannah River Site - EM[a]	N/A	N/A	N/A	86	90	88	97	96	94	89	89
Waste Isolation Pilot Plant	81	90	81	100	100	98	98	96	17	86	84

Source: GAO analysis of Department of Energy data. | GAO-19-5

[a]The EM portion of the Savannah River Site (SRS) contract for fiscal years 2006 through 2008 had multi-year award fee targets that did not align with individual fiscal years. This table represents only EM's portion of SRS fees. Fee data on the portion of SRS activities rated by the National Nuclear Security Administration can be found in Appendix VI.

Figure 8: Annual Fee Earned by the Office of Environmental Management's Management and Operating Contractors, Fiscal Years 2006-2016[73]



Source: GAO analysis of Department of Energy data. | GAO-19-5

[72] U.S. Government Accountability Office, "DEPARTMENT OF ENERGY: Performance Evaluations Could Better Assess Management and Operating Contractor Costs."

[73] U.S. Government Accountability Office.

3. Extra Information on the Draft Consent-Based Siting Process

a. Principles for the Consent-Based Siting Process

The following principles were the principles used in designing the draft of the consent-based siting process. These were decided upon by the DOE through analysis of research and feedback from public engagement sessions:[74]

- *Prioritization of Safety* – The highest priority will be to site, design, construct, operate, and close nuclear waste management facilities in a safe and secure manner that is protective of human health and the environment.
- *Environmental Responsibility* – The siting process will support the development, construction, operation, and closure of facilities that successfully isolate radioactive materials from the environment and use best practices with respect to rigorous planning, implementation, and monitoring.
- *Regulatory Requirements* – The siting process will support the development of facilities that meet or exceed applicable regulatory requirements. Regulatory requirements will be applied rigorously and transparently.
- *Trust Relationship with Indian Tribes* – The siting process will respect tribal sovereignty and self-determination, lands, assets, resources, and treaty and other federally recognized and reserved rights. The process will take into account siting impacts on sacred tribal lands, and other areas and resources of religious or cultural significance. (The importance of recognizing Tribes' special trust relationship with the U.S. federal government in the siting process is discussed further in Section 5.4 of this document; siting considerations are also discussed in Chapter 6.)
- *Environmental Justice* – The process will pursue fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income. The process will also embrace environmental justice principles, and comply with federal requirements and guidance on these issues.
- *Informed Participation* – Consent is not meaningful unless it is informed. This means that the implementing organization[15] will share information and provide financial and technical resources to communities as needed to enable effective participation and provide for informed decision-making.
- *Equal Treatment and Full Consideration of Impacts* – The siting process will be conducted in a manner that is considerate of parties who are or may reasonably be affected, identifies and shares information about potential impacts, and makes explicit the role of fairness and equity considerations in its decision-making.

[74] U.S. Department of Energy, "Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste."

- *Community Well-being* – Communities will want to weigh the potential opportunities and risks of hosting a facility, including the social, economic, environmental, and cultural effects—both positive and negative—it may have on the community. To ensure that the siting process is fair and durable, consideration of all these impacts and benefits will be integral to the siting process.
- *Voluntariness/Right to Withdraw* – Participation in the consent-based siting process will be voluntary. Further, a community that volunteers to be considered for hosting a nuclear waste management facility will reserve the option to reconsider and withdraw itself from further participation up to the point that a binding agreement has been signed. Provisions specifying when and on what grounds agreements could be terminated or amended beyond that point could be negotiated as part of the agreement.
- *Transparency* – The siting process will be open to input throughout and transparent with respect to how decisions are made. Every effort will be made to share information and input with all participants in the process and explain how this information and input is being considered or applied.
- *Stepwise and Collaborative Decision-Making that is Objective and Science-Based* – The process will be implemented in discrete, transparent, and easily observed and evaluated steps, in consultation with the public, interested stakeholders, and affected parties. Decisions will be based on sound science and siting considerations and regulatory requirements will be applied rigorously and transparently. The siting process will recognize the value of supporting robust participation, encouraging multiple applications, and keeping options open, especially in the early phases of the siting process.

b. 2017 Draft Consent-Based Siting Process

Table 3: Draft of the Consent-Based Siting Process[75]

Phase I	**Initiate Consent-Based Siting Process and Invite Communities to Learn More** *Rough estimate of schedule: 1–3 years to initiate the consent-based siting process for each type of facility.*
Step 1	**Implementing organization obtains legislative authority and funding.** Initiate a consent-based siting program, with sufficient authority and funding, to collaborate with communities and stakeholders at the local, state, and tribal levels to site waste management facilities.
Step 2	**Implementing organization initiates the consent-based siting process.** Provide information, answer questions, and engage with the public on consent-based siting and an integrated waste management system to store and dispose of nuclear waste. Discuss consent-based siting with potentially interested communities and stakeholders, and encourage mutual learning between communities and the implementing organization. Information-sharing, open discussion, and mutual learning activities continue throughout the consent-based siting process. The NRC, EPA, and other agencies (if applicable) initiate development of generic repository standards.
Step 3	**Implementing organization issues a funding opportunity for communities to learn more.** Establish a federal grant program and issue a funding opportunity for communities interested in learning more about consent-based siting, nuclear waste management, siting considerations, and the role a waste management facility (or facilities) may play in the community. Additional funding opportunities may be issued in later steps of the process based on Tribal, state, community, and program needs.
Step 4	**Communities express interest in learning more respond to funding opportunity.** Communities respond to the funding opportunity notice indicating an initial interest in learning more about consenting to host an interim storage facility or repository. Briefings, meetings, information materials, and opportunities for open discussion are made available to communities that express interest. Communities submit grant applications.
Step 5	**Implementing organization evaluates applications and awards grants.** The implementing organization reviews grant applications and evaluates whether the community has the potential to play a role in an integrated waste management system. This early-stage evaluation focuses on high-level, readily detectable factors that could exclude a community from further consideration, such as proximity to major population centers, national parks, or other areas of special significance. This step relies on readily available information, such as reports of the U.S. Geological Survey, state geological agencies, academic papers, and National Laboratory-developed geologic information systems with data relevant to both surface facilities and underground repositories. The implementing organization awards grants based on criteria in the funding opportunity notice to enable communities to learn more. The implementing organization works closely with communities to encourage mutual learning, establish an open dialogue, identify potential environmental justice concerns, and support community planning efforts to assess whether a facility fits into the community's long-term vision

[75] U.S. Department of Energy.

	and well-being, including economic benefits and challenges. This engagement with the implementing organization continues throughout the consent-based siting process. The NRC and EPA, and other agencies (if applicable) continue development of repository standards.
Step 6	**Community requests preliminary assessment of site.** The community decides whether to request a preliminary assessment to determine whether a site or sites within the community have the potential to possess the geological, geographical, and technical attributes expected for hosting a SNF and/or HLW management facility. Communities may choose to hire their own experts to help them evaluate if they wish to proceed to a preliminary assessment and continue their involvement with the siting process.
Phase II	**Site Assessment** *Rough estimate of schedule: 1–2 years for interim storage facility; 2–4 years for repository.*
Step 7	**Implementing organization conducts preliminary site assessment.** At the request of the community, the implementing organization conducts a preliminary site assessment. This includes site evaluation activities to assess technical concerns and feasibility, infrastructure issues, local socio-economic and environmental conditions, and potential impacts. The assessment begins with an extensive analysis based on the full range of existing information that can be obtained in a reasonable time. In addition to the information gathered in the first phase, data sources considered may include a more comprehensive review of literature and related studies in the public domain and the private sector (when available); various meteorological, environmental, socioeconomic, and transportation studies conducted in the affected area by federal or state agencies; and available data from existing exploratory boreholes or other existing field investigations in the region of the site. If this analysis identifies additional data that are necessary to support a decision to conduct a detailed site assessment in Phase III, some additional activities may be undertaken following completion of required environmental reviews, including surface investigations such as geologic mapping and geophysical surveys, compilations of satellite imagery data, aerial photography, or limited surface-disturbing work such as trenching. After analysis of the information collected, the implementing organization completes the assessment, shares the results with the community, and determines whether a site (or sites) within the community is eligible to be considered for a detailed site assessment. The decision-making process used to determine whether sites are suitable for a detailed assessment and the bases for the decision are discussed clearly and openly with the community. The NRC and EPA, and other agencies (if applicable) propose generic repository standards.

Phase IV	**Agreement** *Rough estimate of schedule (note that times overlap with the prior phase): 1–2 years for interim storage facility; 2–5 years for repository.*
Step 11	**Community offers the terms and conditions on which they would like to proceed.** Following an affirmative decision to pursue hosting a facility, the community drafts and proposes the terms and conditions of an agreement with the implementing organization to host the facility. This includes what types and amounts of SNF and/or HLW the community would consent to accepting at the proposed facility, the type of facility (storage, disposal, or both) that would be considered, and under what terms and conditions.
Step 12	**The community and the implementing organization negotiate and ratify an agreement.** The community and the implementing organization discuss, collaborate, and negotiate to achieve a workable, durable agreement. The implementing organization and the community determine whether to enter into a formal agreement.
Step 13	**The community and the implementing organization finalize the agreement.** The community determines the method to be used to ratify the agreement that the community considers suitable. The implementing organization and community accept terms of the agreement, and all required parties sign. Agreement is approved by necessary parties and finalized.
Phase V	**License, Construct, Operate, and Close** *Rough estimate of schedule:* *Licensing Process: 2–3 years for interim storage facility; 3–5 years for repository* *Construction: 18–24 months for interim storage facility; 7–10 years for repository* *Operation: 40–100 years for interim storage facility; 30–150 years for repository*
Step 14	**License facility.** The implementing organization and the community work together to finalize the facility design, safety analysis, and license application for the proposed facility (or facilities). The license application is submitted to the NRC for review and decision. The NRC considers the application under the regulations applicable to the specific type of facility proposed with opportunities for involvement by other parties as provided in those regulations.
Step 15	**Construct and operate the facility.** Assuming receipt of the required authorization from the NRC and other agencies and in accordance with the formal agreement, the implementing organization constructs and then operates the facility. Preparation for transportation and other logistical and infrastructure steps are finalized prior to start of operation. The implementing organization continues to work collaboratively with the community to ensure commitments to the community are maintained and upheld throughout the lifetime of the facility.
Step 16	**Close and decommission the facility.** The implementing organization and the community work together to close and decommission the facility under the terms agreed to in the formal agreement and consistent with applicable statutory and regulatory requirements.

Step 17	**Monitor the site post closure and maintain communication.** The implementing organization and the community continue to monitor the site to ensure safety and protection of people and the environment. The program implementer and the community maintain open, two-way communication.

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