Integrated Waste MANAGEMENT

CONSENT-BASED SITING

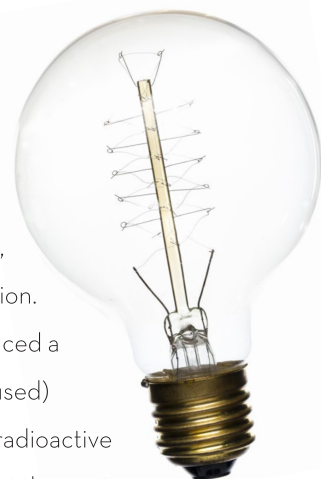
2016

Contents

1 Background and Context

WHERE DO WE STAND NOW?

AMERICA'S NUCLEAR WASTE MANAGEMENT CHALLENGE



Nuclear technology has been used in the United States since the early 1940s for national defense, research and development, and electric power generation. These activities have produced a large quantity of spent (or used) nuclear fuel and high-level radioactive waste. These materials are at the center of a long-standing debate about how to manage America's nuclear legacy.

By far the largest inventory of spent nuclear fuel comes from commercial electricity generation: approximately 70,000 metric tons of uranium at the end of 2013.[1] The U.S. Department of Energy (DOE) estimates continued operation of the current fleet of nuclear power reactors could increase the total inventory of spent nuclear fuel to approximately 140,000 metric tons of uranium.[2] Nearly all the existing commercial spent nuclear fuel is being stored at the reactor sites where it was generated, either submerged in pools of water (wet storage) or in shielded casks (dry storage). High-level radioactive waste, most of which was generated by reprocessing for defense nuclear activities, consists of roughly 90 million gallons of high-level waste liquids, sludges, and solids.[3] Most of the defense high-level radioactive waste in DOE's current inventory is stored at the Hanford and Savannah River sites and is planned to be (or has already been) vitrified into a glass form. DOE also manages defense high-level radioactive waste in a dry calcine form at the Idaho National Laboratory. Finally, DOE stores some commercial high-level radioactive waste at the West Valley site and is managing additional quantities of spent fuel from research and defense activities (totaling approximately 2,200 metric tons[4]) at a number of its sites. **FIGURE 1** indicates the location of the 74 commercial reactor sites and 5 DOE sites where spent nuclear fuel and high-level radioactive waste are currently being stored. Note that the figure given for commercial reactor sites includes 13 shutdown sites where there is no longer an operating reactor.

Under current law, the federal government—and specifically DOE—is responsible for providing the safe and permanent disposal of spent nuclear fuel and high-level radioactive waste. In fact, under the Nuclear Waste Policy Act, DOE was to have begun accepting spent nuclear fuel and removing it from contract holders (e.g., commercial power utilities) by 1998. Additionally DOE has agreements with the states of Idaho, South Carolina, and Washington regarding the cleanup of former weapons production sites.

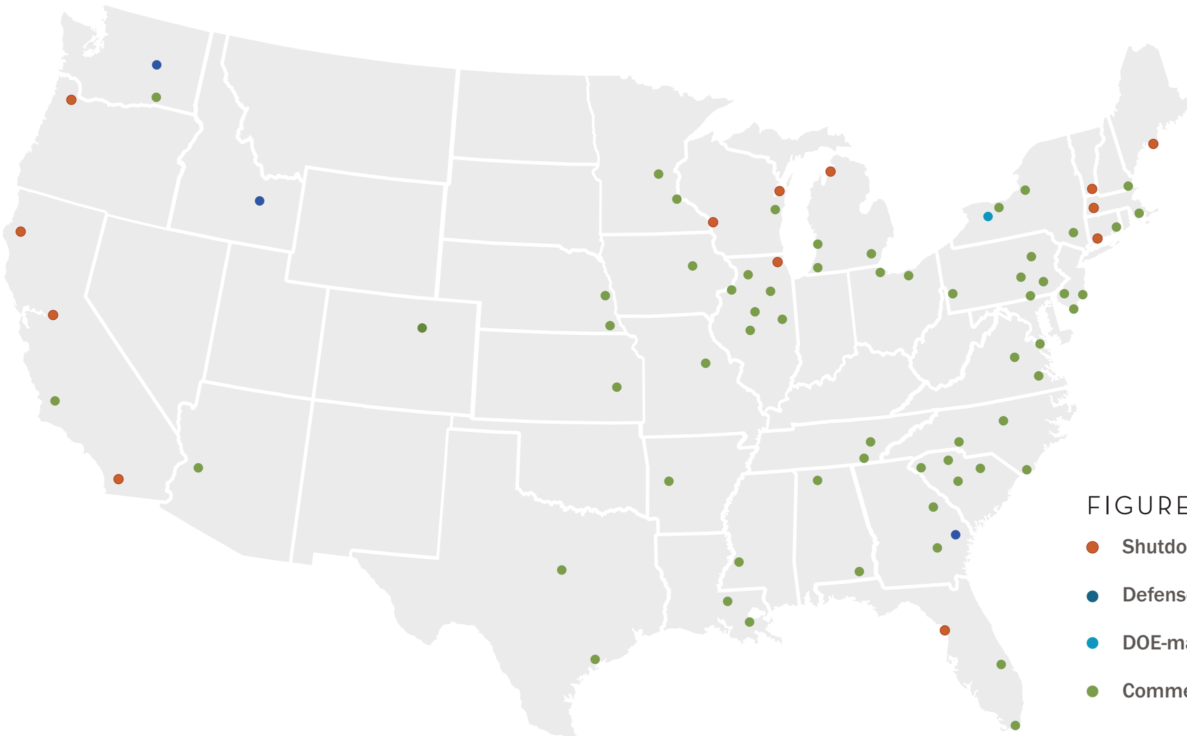


FIGURE 1

Spent nuclear fuel and high-level radioactive waste pose a disposal challenge because these materials remain radioactive and therefore require isolation from the public for long periods of time. The expert consensus, nationally and internationally, is that disposal in a deep geological repository offers the best practical solution for achieving long-term isolation. Further, many locations around the country offer potentially suitable geological conditions for a disposal repository. The more intractable challenge to date has been siting such a facility. In fact, state (and sometimes local) opposition has thus far stymied all efforts to move forward with either a repository or consolidated storage site. Secretary Moniz articulated the core challenge:

"Any workable solution for the final disposition of used fuel and nuclear waste must be based not only on sound science but also on achieving public acceptance at the local, state and tribal levels."[5]

HOW DID WE GET HERE?

A BRIEF HISTORY OF U.S. NUCLEAR WASTE MANAGEMENT EFFORTS

Efforts to find a long-term solution for managing spent nuclear fuel and high-level radioactive waste date back to 1957, when the National Academy of Sciences recommended burying radioactive waste in geologic formations as the best permanent disposal option.[6]

Congress endorsed this approach in the Nuclear Waste Policy Act of 1982 (NWPA), which has provided the basic policy framework for U.S. efforts to manage commercial spent nuclear fuel and high-level radioactive waste ever since. The Act established procedures for evaluating and selecting sites for geologic repositories and set key milestones for federal agencies to meet in implementing the policy. The NWPA charges DOE with the responsibility to site a deep geologic repository. In addition, it directs the Environmental Protection Agency (EPA) to develop standards to protect the environment from offsite releases of radioactive material in repositories. The NWPA also charges the Nuclear Regulatory Commission (NRC) to license DOE to construct and operate a repository only if it meets EPA's standards and all other relevant requirements.

After passage of the NWPA, DOE continued studying several possible repository sites, until Congress passed the Nuclear Waste Policy Amendments Act of 1987, which directs DOE to evaluate only Yucca Mountain in Nevada. Due to controversy, cost escalation, and legal challenges, formal DOE recommendation of the Yucca Mountain site to the President, the President's recommendation of Yucca Mountain to Congress, and subsequent congressional approval of the site were delayed until 2002, four years past the date on which DOE was supposed to begin accepting waste. DOE submitted a license application to the NRC to construct a repository at Yucca Mountain in 2008. The State of Nevada strongly opposed each of these steps and the selection of the Yucca Mountain site itself remained highly controversial, with numerous legal and technical objections throughout the site evaluation and license application process. Similarly, efforts to site and develop federally managed interim storage facilities pending the availability of a disposal repository also encountered opposition at the state level and all were unsuccessful.

In 2009, with the timeline for opening a repository pushed back by two decades, and no end to opposition in sight, DOE determined a geologic repository at Yucca Mountain to be unworkable due to continued lack of acceptance. In 2010, DOE established the Blue Ribbon Commission on America's Nuclear Future (hereafter "Blue Ribbon Commission") to recommend a new

"plan of action for the management and disposal of the nation's used nuclear fuel and high-level radioactive waste."

The Blue Ribbon Commission issued a final report in January 2012 that reaffirmed the broad outlines of the waste management policy adopted in 1982, but announced several new steps to reset the program and restart progress toward a long-term solution to the nuclear waste issue.[7] Key recommendations included establishing a new entity to manage the U.S. nuclear waste program and using a consent-based process to site future storage and disposal facilities.

In January 2015, the NRC issued the final volume of its staff review of the Yucca Mountain license application. While the review concluded that DOE had successfully demonstrated the proposed repository would meet all applicable technical performance requirements, NRC staff did not recommend issuance of a construction authorization because of outstanding issues related to land withdrawal and water rights. Specifically, congressional action would be needed to give DOE the requisite ownership and control of land needed for the repository. In addition, DOE would need water rights from the State of Nevada. Thus, the challenges posed by Nevada's opposition to the selection of the Yucca Mountain site remain, underscoring the need for an initiative that relies on a consent-based process to gain acceptance for a repository site at local, state, and tribal levels.

FIGURE 2

History of Nuclear Waste in the United States.

TIMELINE

Development of Nuclear Power

- 1934 — Enrico Fermi splits the atom and achieves the world's first nuclear fission
- 1942 — Manhattan Project forms to build the atomic bomb for use in World War II
- 1945 — U.S. produces first nuclear weapons
- 1953 — U.S. launches the first nuclear-powered submarine, *the U.S.S. Nautilus*
- 1954 — Congress passes the Atomic Energy Act of 1954, providing direction for the peaceful use of atomic energy
- 1955 — U.S. begins using nuclear power to generate electricity

Development of Geologic Disposal

- 1957 — National Academy of Sciences recommends geologic disposal for disposing of nuclear waste
- 1970 — U.S. begins a search for potential repository sites
- 1970 — Lyons, Kansas site selected as the first national repository
- 1972 — Government withdraws from activities at Lyons site due to technical uncertainties and public opposition

Nuclear Waste Policy Act and Yucca Mountain

- 1982 — Congress passes NWPA, establishing process for selecting a disposal site
- 1986 — DOE recommends three sites for further study, including Yucca Mountain
- 1987 — Congress amends NWPA, directing DOE to study only Yucca Mountain
- 1988-2002 — DOE studies Yucca Mountain extensively
- 1998 — DOE misses deadline to begin accepting spent nuclear fuel
- FEB 2002 — DOE recommends Yucca Mountain as the nation's first disposal site and President Bush submits recommendation to Congress
- APR 2002 — Nevada Govenor Guinn submits official notice of disapproval to Congress
- JUL 2002 — President Bush signs joint resolution approving Yucca Mountain as repository site
- 2008 — DOE submits license application for construction of repository to NRC
- 2009 — Administration determines Yucca Mountain is not a workable solution; DOE suspends activities at the site

The Blue Ribbon Commission and Consent-Based Siting

- 2010 — Secretary of Energy Chu establishes the Blue Ribbon Commission on America's Nuclear Future (BRC)
- 2012 — BRC recommends DOE adopt a consent-based approach to siting nuclear waste facilities, including consolidated interim storage and geologic disposal sites
- 2013 — DOE releases *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* based on the recommendations from the BRC
- 2015 — Secretary of Energy Moniz announces DOE will pursue a consent-based approach to siting facilities for interim storage, as well as disposal of defense and commercial waste

WHERE DO WE GO FROM HERE?

A WINDOW OF OPPORTUNITY FOR A NEW APPROACH

Building on the recommendations of the Blue Ribbon Commission, DOE issued the Administration's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-level Radioactive Waste* (the Strategy) in January 2013.[8] Subject to appropriate authorizations from Congress, the Strategy calls for implementing an integrated waste management system with the following elements:

- a pilot interim storage facility, initially focused on accepting spent nuclear fuel from shutdown commercial reactor sites;
- a full-scale consolidated interim storage facility that provides greater capacity and flexibility within the waste management system; and
- permanent geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste.

DOE intends to pursue the phased, adaptive approach recommended by the Blue Ribbon Commission to achieve these objectives and is committed to launching a consent-based process for siting these facilities.

Recognizing that a consent-based siting effort will face many of the same difficulties encountered in the past, recent developments have created new opportunities for meaningful progress. First, the Blue Ribbon Commission's report provided a framework for moving forward, including a number of actionable recommendations that have gained support from a wide range of policy makers and stakeholders. At the same time, voluntary efforts to site a consolidated waste storage facility have emerged in Texas and New Mexico, where a private waste management company and a consortium of local governments, respectively, have indicated interest in developing such a facility.[9] Together with recent progress in other countries that are moving forward with their own nuclear waste management programs, these efforts offer lessons that can inform a new, consent-based siting effort at the federal level. In addition, an increasing number of nuclear plants are reaching retirement. With no facilities in place to accept the spent fuel from decades of electricity production, these shutdown sites will likely add urgency to the quest for solutions.

A long-term strategy for managing spent nuclear fuel and high-level radioactive waste is needed for many reasons: to safeguard public health and the environment, to mitigate security and proliferation risks, to protect taxpayers from ballooning financial liability as nuclear utilities seek compensation for the federal government's failure to meet its waste management obligations, and—not least—to meet a clear ethical obligation to avoid burdening future generations with nuclear waste they had no part in creating. For these reasons, DOE is committed to finding sustainable solutions for managing our nation's spent nuclear fuel and high-level radioactive waste by developing a consent-based approach to siting.

NEXT STEPS IN DOE'S CONSENT-BASED SITING EFFORT

Looking forward, DOE plans to conduct a consent-based siting process in multiple phases. The first phase involves engaging with the public and interested parties on what they believe to be the most important elements to consider in a consent-based siting process. The second phase will focus on designing a consent-based siting process to serve as a framework for collaborating with potentially interested host communities. In subsequent phases, the Department will use the resulting consent-based process to work with interested communities.

Key areas of inquiry in the first phase include:

- How can the Department ensure that the process for selecting a site is fair?
- What models and experience should the Department use in designing the process?
- Who should be involved in the process for selecting a site, and what is their role?
- What information and resources do you think would facilitate your participation?
- What else should be considered?

As it explores these initial questions and throughout subsequent phases of the consent-based siting process, the Department is

committed to a collaborative approach that fully takes into account the public's values, perspectives, and interests.

This means designing an approach that encourages citizens, communities, and stakeholders to (1) engage with each other in a productive consultation process, (2) be responsive to requests for additional information and clarification, (3) work toward shared objectives, and (4) collaborate on effective and lasting solutions.

2 Consent-Based Siting

KEY FEATURES OF A CONSENT-BASED APPROACH TO SITING

The 2012 report of the Blue Ribbon Commission recommended a new approach to siting that differs in fundamental respects from the prescribed, "top-down" approach that has characterized the U.S. repository program since the Nuclear Waste Policy Amendments Act of 1987 limited DOE's consideration of potential repository sites to a single location, at Yucca Mountain in Nevada.[10] Based on a review of past experience with siting nuclear waste facilities in the United States and overseas, the Blue Ribbon Commission concluded that success would be more likely with an approach to siting that is:

> **CONSENT-BASED** in the sense that affected communities have an opportunity to decide whether to accept facility siting decisions and retain significant local control.
>
> **TRANSPARENT** in the sense that all stakeholders have an opportunity to understand key decisions and engage in the process in a meaningful way.
>
> **PHASED** in the sense that key decisions are revisited and modified as necessary along the way rather than being pre-determined.
>
> **ADAPTIVE** in the sense that the process itself is flexible and produces decisions that are responsive to new information and new technical, social, or political developments.
>
> **STANDARDS- AND SCIENCE-BASED** in the sense that the public can have confidence that all facilities meet rigorous, objective, and consistently applied standards of safety and environmental protection.
>
> **GOVERNED BY** partnership arrangements or legally enforceable agreements between the implementing organization and host states, Tribal Nations, and local communities.

Final Report of the Blue Ribbon Commission on America's Nuclear Future, p.47

DOE concurs with the Blue Ribbon Commission's findings on the advantages of an explicitly adaptive, phased, and consent-based approach.
In the 2013 *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, the Administration described its view of what it means to proceed in a consent-based fashion:

> In practical terms, this means encouraging communities to volunteer to be considered to host a nuclear waste management facility while also allowing for the waste management organization to approach communities it believes can meet the siting requirements. Under such an arrangement, communities could volunteer to provide a consolidated interim storage facility and/or a repository in expectation of the economic activity that would result from the siting, construction, and operation of such a facility in their communities.

KEY QUESTIONS FOR A CONSENT-BASED SITING PROCESS

Inherent in the concept of a phased, adaptive, and consent-based approach is the recognition that many of the specific steps and issues to be resolved in the siting process cannot be determined in advance. Nonetheless, it is useful to identify some of the questions that will have to be addressed as the process moves forward:

1. How to define consent and how/whether consent should be codified. For example, the Blue Ribbon Commission offered the view that "a good gauge of consent would be the willingness of the host [jurisdictions] to enter into legally binding agreements…that can protect the interests of their citizens." Defining consent, deciding how consent should be codified, and determining whether or how consent would need to be ratified by Congress and by potential host jurisdiction(s) are among the issues that need to be addressed early in the siting process.

2. How to provide for "off-ramps" or opt-out mechanisms. To be willing to be considered as potential host sites, communities, Tribal Nations, and states will want to retain some unilateral ability to withdraw from the siting process if they so choose, at least up to a point. As the Blue Ribbon Commission pointed out, the level of public acceptance and support for a particular facility at a particular site is likely to fluctuate over time. In early negotiations between the federal government and potential host states, Tribal Nations, and communities, the parties will need to decide at what point in the process the right to opt out unconditionally should expire. The circumstances under which a community, Tribal Nation, or state could opt out conditionally (or for cause) beyond that point, and what the mechanism(s) for opt out would be at different stages of the siting process, will likewise need to be negotiated.

3. How to balance the need for flexibility and adaptability in a staged process with the need for assurance that the process will move forward. Rigid deadlines have been a hallmark of previous waste management efforts that have not worked well. At the same time, Congress, stakeholders, and the public must have confidence that progress is being made. The Blue Ribbon Commission report recommends that key milestones be established early in the siting process as a way to retain flexibility within the program while also providing visible markers or indicators against which progress can be measured.

4. How and by what means to provide the financial support that states, Tribal Nations, local authorities, and non-governmental organizations (NGOs) will need to participate meaningfully in the siting process. Given the technical complexity of the nuclear waste issue, states, local authorities, and citizens groups are likely to need help accessing the technical information and expertise needed to participate as full partners in the siting process. They may also need additional support to cover the direct costs of participation, such as travel to meetings.

5. How to establish and maintain the information-sharing and transparency mechanisms that will be needed to build confidence in the process, assure all participants that they are working from the same shared basis of knowledge, and establish trust that future facilities will be sited and operated in a manner that fully protects the public and the environment. DOE has endorsed the proposition that prospective host jurisdictions must be recognized as partners and that "[p]ublic trust and confidence is a prerequisite to the success of the overall effort, as is a program that remains stable over many decades."[11]

6. How to negotiate the role of states, Tribal Nations, and communities not only in the consent-based siting process, but also in the ongoing oversight of a facility after it is sited and begins operating. The Blue Ribbon Commission report provides a succinct description of the challenge: "Clearly, locating and constructing facilities for the management and disposal of [spent nuclear fuel] and [high-level radioactive waste] will require complex and possibly lengthy negotiations between the federal government and other relevant units of government. In these negotiations, it will be important to define the roles, responsibilities, and authorities of host state, tribal, and local governments both throughout the siting and licensing process and once a facility is operational."[12] The Blue Ribbon Commission also notes that allowing for a measure of state and local control over aspects of regulation, permitting, and oversight has proved helpful in past siting efforts, notably in the case of the Waste Isolation Pilot Plant (WIPP) facility in New Mexico.

7. How to consider potential benefits for host states, Tribal Nations, and communities in the siting process. As the Blue Ribbon Commission noted, "it will be important to demonstrate that the decision to host a facility can deliver real benefits (economic and otherwise) to the Tribe, state, and local community."[13] Thus, benefits will be an important topic in the consent-based siting process. The Blue Ribbon Commission report further notes that the discussion need not be limited to financial options—benefits could also take the form of local preferences in hiring and in the procurement of goods and services, infrastructure investments, and the opportunity to host co-located research and development facilities or other activities that would provide local benefits.

The above list of questions is by no means exhaustive—rather, it is intended to provide a sense of the kinds of issues that are likely to come up early in the consent-based siting process. Moreover, DOE is aware that some questions can be addressed (and in some cases must be addressed) relatively early in the process, while answers to others may need to evolve. Many of the key issues can only be settled through a process of negotiation. Thus, an important goal of DOE's early meetings is to begin soliciting input on these issues.

SITING EFFORTS IN OTHER COUNTRIES

A number of countries around the world have been grappling with the issue of nuclear waste disposal and a few countries have made progress toward identifying and developing an actual repository site. In November 2015, the government of Finland approved construction of the first geologic repository for disposal of spent fuel in the world.[14] In Sweden, regulators are currently reviewing a license application for a repository. As of the end of 2015, however, no country is operating a deep geological facility that is accepting high-level nuclear waste and spent nuclear fuel. The countries that appear best positioned to achieve success in opening a repository have all earned social acceptance for a specific facility at a specific site. In other words, despite their unique political, regulatory, and cultural environments, the countries that have been most successful have pursued a siting process that prioritizes dialogue and public and stakeholder involvement along with technical issues. According to one description of recent waste management developments in member countries of the Organisation for Economic Co-operation and Development (OECD), "a trend can be seen in OECD countries towards implementing forms of public involvement that require new or enhanced dialogue amongst all concerned parties. As parties to this dialogue, regional and local political players and civil society take an active role where appropriate in decisions concerning radioactive waste management, including the siting and implementation of geological repositories."[15]

In the course of pursuing robust public engagement processes, various national governments have developed new competencies in creating and sustaining dialogue with local communities. A few key observations, drawn from the more successful examples of international experience with siting nuclear waste management facilities, are likely to be relevant to future consent-based siting efforts in the United States:

- Repository development programs in different countries have reflected the political and cultural circumstances of those countries.
- Most siting processes faced setbacks in the early stages. In many cases, these setbacks prompted revisions that had to be implemented before the process could move forward.
- Local government is always involved as the representative of the community and in all cases (with the single exception of Switzerland), local government has had a decision-making role in the siting process.
- Elected representatives of the community that is closest to where the disposal facility will be built (in other words, the local municipality) tend to be the local decision maker in the siting process.
- Engagement with and understanding of the issues, and overall support for the proposed facility are often higher at a local level than at a regional or national level.

- The benefits of accepting a geologic repository and the benefits that are made available to potential host communities have varied from country to country in terms of type, scope, amount, and when they become available. In a number of countries, host communities can access benefits before the facility is constructed.[16]

Many of these elements are echoed in another list of features common to successful siting processes that appears in a recent report on the topic by the U.S. Nuclear Waste Technical Review Board (NWTRB).[17] The NWTRB notes that these efforts:

- Use multiple techniques and approaches to communicate and directly engage with interested and affected parties
- Embed the implementer's representatives within the community
- Create clear rules—that are agreed to in advance—to govern the relationship between the implementer and the community
- Establish a group that is broadly representative of the community, to foster ongoing interactions with the implementer
- Specify the basis for when, why, and how a community can withdraw from the siting process
- Provide sufficient funding to allow a community to participate fully in the process
- Provide independent review of the implementer's technical arguments either by experts chosen by the community or by an ongoing external group
- Encourage the implementer to be open and responsive to questions and challenges from the community
- Create a partnership between the community and the implementer to support repository development if the former agrees to host the facility
- Clearly articulate the benefits the community is likely to receive from hosting a deep mined, geologic repository

As DOE moves forward with a consent-based approach to siting in the United States, the Department will continue to look internationally for lessons and insights and will keep abreast of the latest developments in other countries' waste management programs.

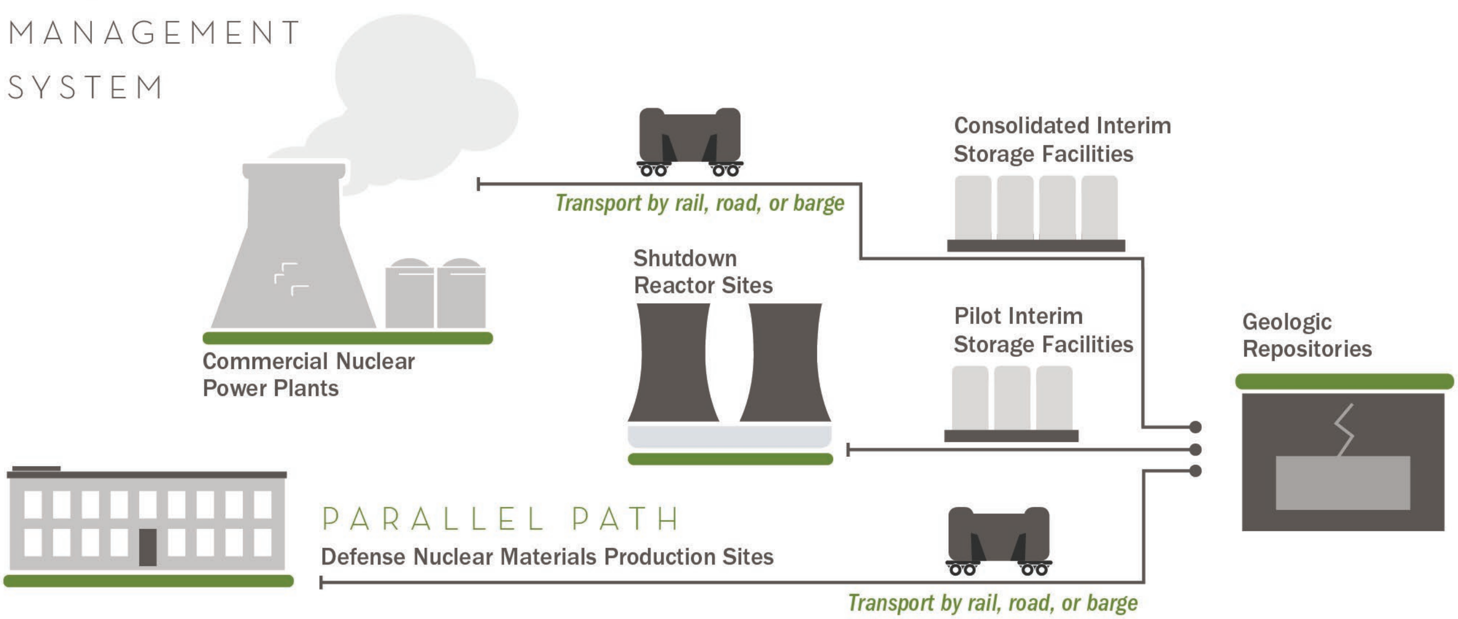
Integrated Waste Management

3

THE NEED FOR AN INTEGRATED WASTE MANAGEMENT SYSTEM

Although the nuclear waste debate in the United States tends to focus on the task of siting and developing a permanent disposal facility, safe and effective management of spent nuclear fuel and high-level radioactive waste requires an integrated system that includes interim storage facilities and robust transportation capabilities, as well as one or more deep geologic disposal repositories. An integrated nuclear waste management system with multiple robust, connected elements will provide the flexibility and adaptability needed to manage the nation's diverse and geographically dispersed inventory of spent nuclear fuel and high-level radioactive waste. The Administration envisions an integrated waste management system with three core elements: **INTERIM STORAGE FACILITIES, DEEP GEOLOGIC DISPOSAL FACILITIES, AND A TRANSPORTATION SYSTEM** that is designed, regulated, and executed for the interstate shipment of spent nuclear fuel and high-level radioactive waste. Each of these elements serves specific and necessary functions within an integrated waste management system.

INTEGRATED WASTE MANAGEMENT SYSTEM



INTERIM STORAGE

The Administration's 2013 *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* calls for the development of a pilot interim storage facility, initially focused on accepting spent nuclear fuel from shutdown reactor sites. Construction of this facility would then be followed by the development of a larger, consolidated interim storage facility, potentially co-located with the pilot facility and/or with a geologic repository. Such a facility would provide needed flexibility in the waste management system and would allow for important near-term progress in implementing the federal commitment to manage these materials.

The development of one or more consolidated storage facilities would provide several specific benefits to the waste management system as a whole. In particular, it would:

1. **ALLOW FOR THE PERMANENT REMOVAL OF SPENT NUCLEAR FUEL FROM SHUTDOWN REACTOR SITES.** There are several reasons to prioritize shutdown reactor sites. First, removing spent fuel would free these sites to be used for other economically or socially productive purposes. Second, the incremental costs of storing spent fuel at otherwise inactive reactor sites are especially high because of the need to maintain active security and monitoring systems just to oversee the spent fuel.[18] Third, as the Blue Ribbon Commission pointed out, communities near these reactor sites were never asked about and never contemplated or consented to the conversion of these sites to indefinite long-term nuclear waste storage facilities.

2. **ALLOW THE FEDERAL GOVERNMENT TO BEGIN MEETING ITS CONTRACTUAL WASTE MANAGEMENT COMMITMENTS.** Under existing contracts with nuclear utilities, DOE should have begun removing spent fuel by 1998. DOE's failure to meet this deadline has prompted utilities to sue for compensation to cover the costs of continued spent fuel storage at these sites. Damages awarded to utilities as a result of these lawsuits are paid out of the U.S. Treasury's Judgment Fund, which is supported by general tax revenues. These liabilities are currently projected to be more than $23 billion over the next 50 years, on top of the more than $4.5 billion the government has already paid in settlements and court judgments.[19]

3. **PROVIDE CRUCIAL FLEXIBILITY FOR THE OVERALL NUCLEAR WASTE MANAGEMENT SYSTEM,** such as the ability to conduct thermal management activities and re-package spent nuclear fuel and high-level radioactive waste if necessary to prepare for permanent disposal, and the ability to regulate the future flow of waste shipments to a permanent disposal facility as circumstances require.

4. **PROVIDE USEFUL LEARNING AND EXPERIENCE,** including opportunities to conduct R&D on the behavior of spent nuclear fuel and high-level radioactive waste over time, as well as to learn from experience with siting, designing, constructing, and operating a storage facility. Much of this knowledge and experience could support the development of a repository.

5. **BUILD CONFIDENCE WITH STAKEHOLDERS AND THE PUBLIC** by demonstrating a consent-based approach and working with a willing and informed community to site a storage facility.

TRANSPORTATION

A safe, secure, and efficient system for transporting spent nuclear fuel and high-level radioactive waste serves as the crucial link between storage and disposal facilities and is a key element of an integrated waste management system. The United States has a long track record of successfully transporting radioactive materials, including spent nuclear fuel and high-level radioactive waste. DOE concurs with the Blue Ribbon Commission's conclusion that existing standards and regulations for the transportation of spent nuclear fuel and high-level radioactive waste administered by DOE, the NRC, the U.S. Department of Transportation (DOT), and state, local, and tribal governments are proven and functioning well.

At the same time, DOE recognizes that the scale and scope of transportation activities needed to move large quantities of spent nuclear fuel and high-level radioactive waste from the dispersed sites where it is currently being stored to future consolidated storage or disposal facilities pose new and significant challenges. The issues to be resolved are technical, infrastructural, logistical, and regulatory. At a management and planning level, the challenges include analyzing and selecting routes and coordinating the functions of multiple federal, state, tribal, and local agencies with jurisdiction over some aspect of transportation system operations and regulation. Finally, given the numerous communities and jurisdictions that would be directly or indirectly affected by a large-scale transportation program, challenges can also be expected to arise with respect to outreach, communications, and emergency response planning.

DOE is currently planning for the development of transportation capabilities to facilitate the acceptance of spent nuclear fuel at a pilot interim storage facility and later at a larger consolidated interim storage facility. Planning activities include evaluating the inventory, transportation interface, and shipping status of spent nuclear fuel at shutdown reactor sites. In addition, DOE has established cooperative agreements with state and regional groups and engaged tribal representatives to begin discussions on transportation planning and emergency response training consistent with NWPA Section 180(c).

DISPOSAL

Expert scientific consensus and official U.S. policy since the early 1980s have established disposal in a deep geological repository as the final pathway for spent nuclear fuel and high-level radioactive waste.

Continued efforts to develop one or more disposal repositories are central to moving forward with an integrated waste management strategy. As the Blue Ribbon Commission pointed out, successful development of a disposal facility is also necessary to build confidence in the overall waste management system and assure stakeholders that interim storage facilities will not become *de facto* permanent disposal sites.

In March 2015, President Obama authorized DOE to move forward with planning for the development of a separate repository for some high-level radioactive waste from the nation's defense activities.[20] Some of DOE's high-level waste is less radioactive, cooler, and easier to handle than commercial spent nuclear fuel. This means that progress toward a disposal facility for this material could benefit from simpler design requirements, greater flexibility in site selection, and fewer licensing and transportation challenges. Thus, a separate repository for some of DOE's high-level radioactive waste could potentially become operational earlier than a repository that includes commercial spent nuclear fuel.

Storage

4

INTERIM WET STORAGE AT REACTOR SITES

As already noted, storage is a necessary part of an integrated waste management system. Absent the availability of a consolidated storage facility or repository, commercial spent nuclear fuel is currently being stored at reactor sites around the nation, including at a number of sites where there is no longer an operating reactor.

Nuclear fuel assemblies are moved into storage after they have been irradiated in a reactor and can no longer efficiently sustain the desired level of fission reactions (typically after four to six years). At this point the fuel is considered "spent" and is removed from the reactor. Because newly discharged spent fuel emits high levels of radiation and heat, it is immediately transferred to a water-filled storage pool inside or adjacent to the reactor building. Immersion in water serves to cool the fuel and shields personnel from exposure to radiation. Typical at-reactor storage pools are made of several feet of steel-lined reinforced concrete and are 40 to 60 feet deep.

Pools are essential at reactor sites to provide storage and cooling for spent fuel assemblies during the initial period (typically at least five years) following their removal from reactor core. As the inventory of commercial spent fuel continues to grow, with approximately 2,000 metric tons of additional spent fuel being generated each year, on average, at-reactor pools are filling up. As a solution, reactor operators now routinely move spent fuel to what is called "dry cask" storage further away from the reactor but still located inside the plant's protected area.[21]

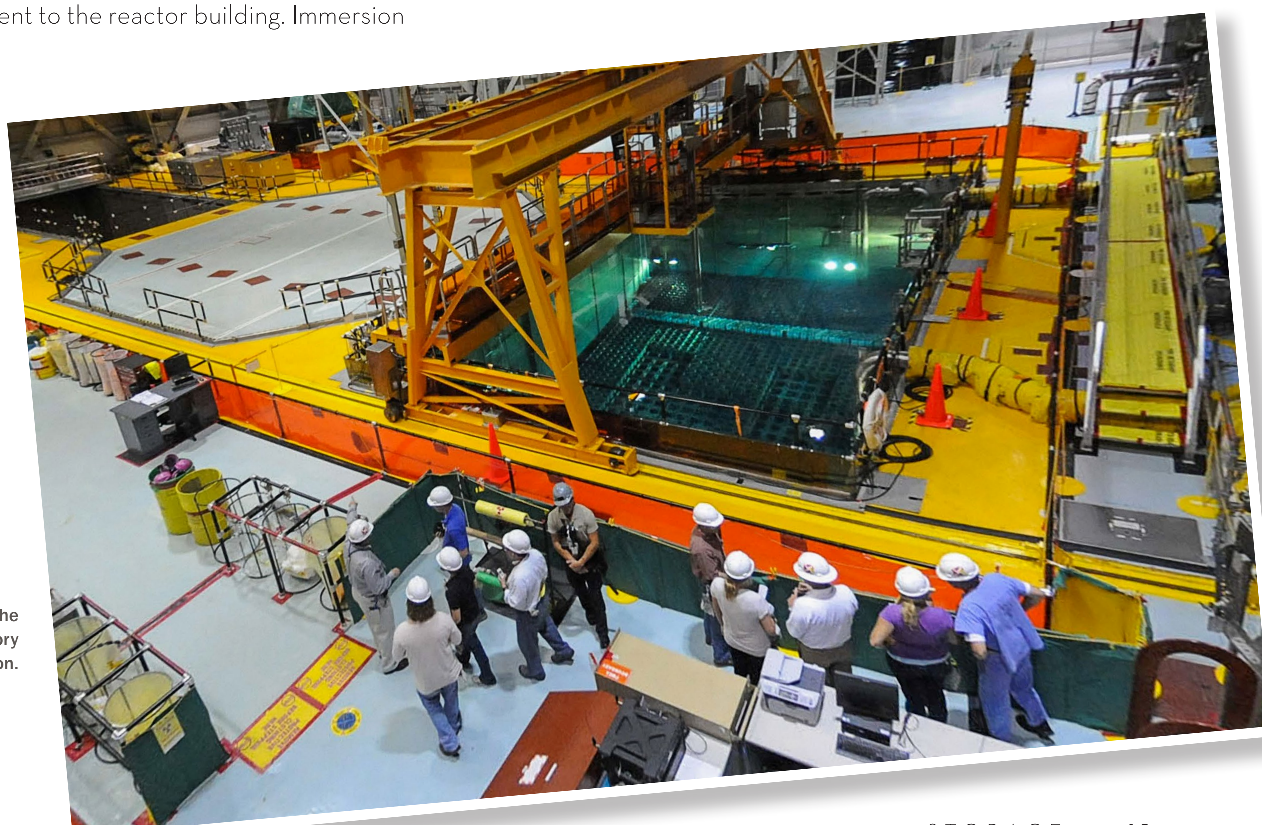


Photo courtesy of the Nuclear Regulatory Commission.

DRY CASK INTERIM STORAGE SYSTEMS

The NRC licensed the first at-reactor dry storage installation in 1986 at the Surry Nuclear Power Plant in Virginia as part of a DOE-sponsored cooperative program with the private sector to demonstrate the dry storage of spent fuel at civilian nuclear power reactor sites.[22] Dry cask storage is licensed at 71 nuclear power plant sites in 34 states,[23] and

about one-third of the nation's commercial spent fuel inventory is in dry cask storage.

Both bare fuel casks and canistered casks are used for the dry storage of spent fuel assemblies. In the former type of storage (using bare fuel casks), spent fuel is placed directly in a basket that is integrated into the storage cask. The bare fuel cask serves as both the radiation shield and the primary boundary for confining radioactive material. It is filled with an inert gas, typically helium, to prevent corrosion that could potentially damage the structural integrity of the cask and its contents. Bare fuel casks are closed using bolted lids with double seals. The seals are monitored to ensure an adequate backfill of inert gas.

In canistered casks, spent fuel is placed in baskets in a steel canister, which is then welded shut. The welded canister serves as the primary boundary for confining radioactive material. As in bare fuel casks, the canister is filled with an inert gas, typically helium, to prevent corrosion. The canister is placed inside a larger dry storage cask made of steel or thick concrete reinforced with an inner steel liner. This cask is often called an "overpack." Depending on the design, the canister/cask combination can be stored in a vertical or horizontal orientation, either above ground on a concrete pad, or below ground.

At present, bare fuel cask storage systems are being used by only four utilities (at a total of five reactor sites) to store a total of 8,798 spent fuel assemblies (in 198 casks).[24] Seven unique bare fuel storage cask systems are currently available from four manufacturers. Three of these seven designs are licensed for both storage and transportation purposes.[25]

Most of the existing inventory of spent fuel in dry storage is being stored in canistered storage systems. Twenty-eight utilities currently use these types of systems to store 75,786 spent fuel assemblies in 1,878 canisters at 66 reactor sites.[26] Fourteen unique canistered storage cask systems are currently available. As part of these 14 storage cask systems, there are currently 53 different dry storage canister designs, with a total of 33 unique canisters potentially in use at sites around the country.[27]

The size of the canister in these dry cask systems varies depending on the design. The number of spent fuel assemblies that can be stored in a single canister likewise varies depending on assembly and canister configuration and canister diameter. Table 1 summarizes typical specifications for existing dry cask systems.

The main purpose of the cask in any dry storage system is to provide shielding from radiation. Casks do not require any additional active equipment such as fans or pumps for cooling. Instead, vents are configured for natural (convective) heat transfer. Nonetheless, storage casks are subject to constant monitoring and surveillance.

Dry cask storage systems are robust and designed to withstand severe environmental conditions and natural disasters such as earthquakes, projectiles, tornadoes, floods, and temperature extremes, as well as terrorist attacks. Casks and storage facilities are certified and licensed by the NRC under federal regulations set forth in the Code of Federal Regulations (10 CFR 72).

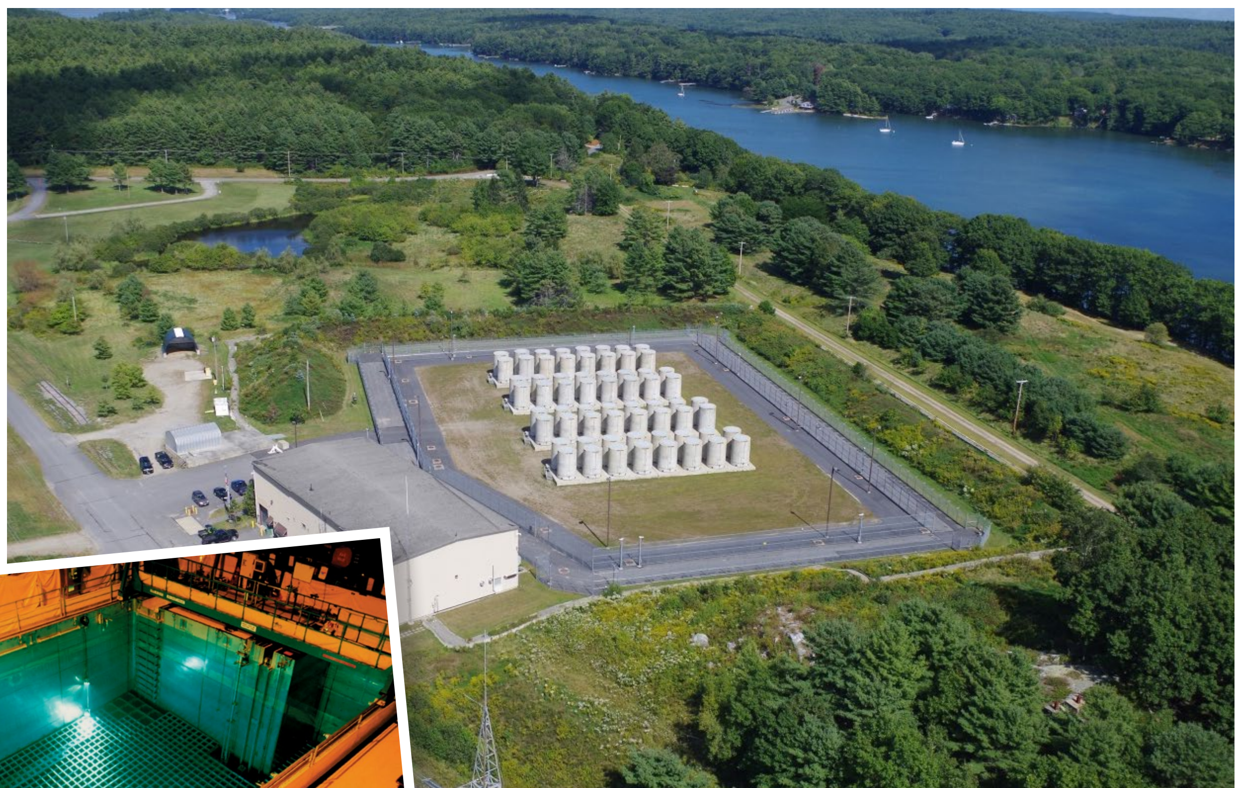
Photo courtesy of Sandia National Laboratory.

Table 1. Characteristics of Typical Dry Cask Storage Systems

Canister Height	114–198 inches
Canister Diameter	37-76 inches
Overpack Outer Diameter	96-140 inches
Capacity	7–37 pressurized water reactor assemblies
	52–89 boiling water reactor assemblies
Weight	
Canister (empty)	55,000–270,000 lbs.
Canisters and Concrete Structure	288,000–425,700 lbs.

CONSOLIDATED INTERIM STORAGE

Consolidated storage (that is, storage of spent fuel from multiple sources at a common site) can be implemented using the same basic wet (pool) or dry (cask) systems currently in use at reactor sites. In addition, other (non-cask) dry storage systems—such as dry vault systems—are in use at some sites in the United States and abroad. Though it is frequently assumed that a substantial part of the inventory at a consolidated storage facility would be held in dry storage, a consolidated facility could also include some wet storage capacity. Some countries, such as Sweden, are using wet storage at their centralized storage facilities. The type(s) of storage system(s) to be used, as well as the capacity and design of that system, would presumably be among the key features to be considered and negotiated during the consent-based process for siting a consolidated storage facility. Resulting design decisions would reflect the specific characteristics of the site and the preferences of the host community.



Independent spent fuel storage installation at Maine Yankee site.

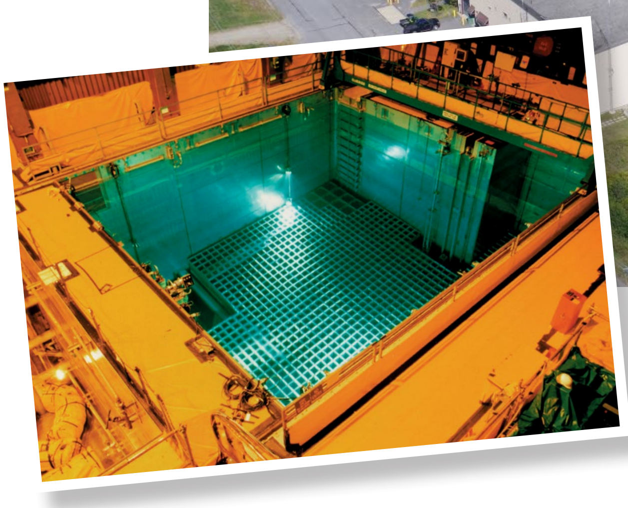


Photo courtesy of the Nuclear Regulatory Commission.

Transportation

5

CURRENT TRANSPORTATION PRACTICES FOR RADIOACTIVE MATERIALS

A safe, dependable transportation system is a necessary link in the operation of any integrated system for managing and disposing of spent nuclear fuel and high-level radioactive waste. At a minimum, waste will need to be moved from wherever it is being stored to a final disposal facility. In addition, waste may need to be moved from the widely dispersed sites where it is currently being stored—nuclear power reactor sites and DOE sites—to one or more consolidated storage sites. Thousands of shipments of spent nuclear fuel have been safely completed worldwide using highways, waterways, and railroads. The safety record for shipments to date has been exemplary: no fatalities, injuries, or environmental damage have been caused by the radioactive nature of the cargo.

Several factors have contributed to this success. Spent nuclear fuel is shipped dry—as a solid, ceramic-like material enclosed in metal tubes—using robust transportation packages. These transportation packages have walls 5 to 15 inches thick made of steel and shielding materials, and a massive high-strength closure lid. The shielding reduces external radiation to low levels that meet DOT and NRC standards for radiation dose to people who might be near the package during transport. The ends of these transportation packages are encased in structures called impact limiters. In the event of an accident, these limiters would crush, absorbing most of the impact energy and protecting the package and its cargo. These transportation packages are specifically designed, constructed, maintained, and operated to safely confine the radioactive materials they hold and prevent these materials from being released into the environment under both normal and accident conditions.

The NRC establishes regulations and standards for the design and construction of spent nuclear fuel transportation packages. The NRC also establishes regulations for the protection of shipments against deliberate, malevolent acts, including conducting security reviews of transportation routes. Each transportation package is designed to maintain its integrity under normal transportation conditions and during hypothetical accident conditions. The integrity of these designs must be demonstrated by computer modeling, partial to full scale testing, or a combination of these methods. The NRC conducts rigorous reviews to certify that spent nuclear fuel transportation packages meet the design standards and test conditions dictated by the regulations.

The DOT has primary responsibility for regulating the safe transport of radioactive materials in the United States. It sets standards for transporting and handling radioactive materials, including requirements for placarding, labeling, documenting the cargo (shipping papers), loading, and unloading. For truck shipments, DOT regulations also specify training requirements for drivers and others involved in the handling and transport of radioactive materials.

Local, state, and tribal governments along shipping routes have responsibility for public health and safety within their jurisdictions and as such, have a role in ensuring the safe and uneventful transportation of spent nuclear fuel and other nuclear waste. DOE works cooperatively with Tribal Nations and states to plan for shipments and prepare routes. State governments, in turn, coordinate with county and local governments and involve them in planning activities. The tasks involved include training public safety officials along routes, coordinating shipment inspections, and responding to inquiries about the shipments from the public and elected officials.

DESIGN REQUIREMENTS FOR PACKAGES USED TO TRANSPORT NUCLEAR WASTE

As already noted, the packages certified to transport spent nuclear fuel and high-level radioactive waste on public thoroughfares are designed to maintain their integrity under normal transportation conditions, as well as during hypothetical accident conditions. The transportation packages must be shown to survive a sequence of four simulated accident conditions involving impact, puncture, fire, and submersion, including:

1. A 30-foot free fall onto an unyielding surface;
2. A puncture test in which the container is allowed to free-fall 40 inches onto a steel rod 6 inches in diameter;
3. A 30-minute, fully engulfing fire at 1475 degrees Fahrenheit; and
4. Immersion under 3 feet of water.

Photo courtesy of the U.S. Navy.

To gauge cumulative effects in the case of an extremely severe accident, analyses of the package designs must assume that these four hypothetical tests are conducted in the sequence listed. Additionally, a separate, undamaged package must be designed to withstand immersion in 50 feet of water.

While the possibility of a fall greater than 30 feet exists in the real world, the totally unyielding surface assumed in the hypothetical test means that 100 percent of the force of the impact has to be borne by the transportation package. Thus it effectively simulates a real-world fall that is well beyond a 30-foot drop. In addition, the cask is assumed to strike the surface in the position that would cause the most severe damage. Similarly, the NRC has studied a number of real-world, long-duration fires to determine their effects on spent nuclear fuel transportation packages and found that the packages successfully withstand these severe fires when exposed to conditions that far exceed the 30-minute, fully engulfing, 1475 degree Fahrenheit fire.

DOE ACTIVITIES RELATED TO TRANSPORTATION

Large-scale shipments of spent nuclear fuel and high-level radioactive waste are not planned in the near term in light of the time required to bring a consolidated storage facility or repository into operation. However, DOE has begun preliminary discussions with Tribal Nations and states across the nation to begin planning for the transportation component of an integrated waste management system and to ensure that final plans reflect input from all groups that are potentially affected by future nuclear waste shipments. In addition to Tribal Nations and states, these efforts involve railroads and other carriers, nuclear utilities, transportation package manufacturers, emergency responders, federal agencies, and other involved parties. DOE already meets at least three times per year with affected groups and state and tribal officials to discuss route selection methodology, training for public safety officials, operational protocols, inspection procedures, and other topics of concern to participants.

In addition to face-to-face meetings, this work is proceeding through webinars, conference calls, and other communication channels.

In its transportation planning activities, the Department is assuming that most commercial spent nuclear fuel shipments will be made by rail. Some shipments will be initiated by barge and/or heavy-haul truck in cases where suitable rail infrastructure does not exist. Rail shipments will be made using specially designed railcars that meet specific Association of American Railroads (AAR) requirements for transporting radioactive materials. These railcars are designed to prevent derailments or to detect conditions that could lead to derailments, enabling the train to be stopped before a derailment occurs. The AAR standard also contains maintenance and inspection requirements for the rail cars, also to prevent derailments. In a typical shipment, certified transportation packages would be loaded on rail cars and escorted by trained federal officers. In addition, state regulations may require that shipments be monitored and, in some cases, escorted by state officials as well.

Cask in transport for disposal at the Waste Isolation Pilot Plant, a deep geologic repository for transuranic waste (not spent nuclear fuel or high-level radioactive waste) near Carlsbad, New Mexico.

6 Geologic Disposal

THE CONCEPT OF GEOLOGIC DISPOSAL

Geologic disposal has long been viewed—on both technical and practical grounds—as the preferred option for the permanent disposition of spent nuclear fuel and high-level radioactive waste. Accordingly, siting and licensing a geologic repository has been a major focus of the U.S. nuclear waste management program, even before the Nuclear Waste Policy Act of 1982 codified the basic policy framework for federal efforts to manage and dispose of spent nuclear fuel and high-level radioactive waste. The emphasis on geologic disposal has since been affirmed by multiple expert studies of the subject, including the 2012 final report of the Blue Ribbon Commission. The Administration's 2013 *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* reiterates the continued commitment to a geologic repository as part of the integrated waste management system.

Geologic disposal of radioactive waste has been studied for more than 50 years.

As early as 1957, the National Academy of Sciences, in a report to the Atomic Energy Commission, recommended burying radioactive waste in geologic formations. In 1962, the Atomic Energy Commission began investigating salt formations, including bedded salt and salt domes, as potential host rock for waste repositories. In 1975, the Energy Research and Development Administration, the federal-agency predecessor to DOE, selected a site near Carlsbad, New Mexico, for a facility—known as the Waste Isolation Pilot Plant or WIPP—to dispose of long-lived transuranic waste. In 1976, the Energy Research and Development Administration also began to investigate other geologic formations and to consider different disposal concepts, including deep-seabed disposal, disposal in the polar ice sheets, and rocketing waste into the sun. After extensive evaluation of the options, DOE concluded in 1981 that disposal in an underground mined geologic repository remained the preferred option. This conclusion was subsequently endorsed by the Nuclear Waste Policy Act of 1982.

In contrast to the hazards posed by toxic materials such as lead, mercury, and arsenic, which do not break down, the hazards associated with radioactive materials decline over time. Early efforts to study disposal options, therefore, focused on the most effective ways, using available technology, to isolate waste long enough for the radiation hazard to decline to low levels. That search led to geologic environments that have remained stable for millions of years and are likely to remain so. Scientists widely agreed that waste packaged in robust, long-lived waste packages and placed in stable geologic environments could be isolated from the biosphere for long time periods.

A key advantage of a geologic repository is that it will not require perpetual human care and will not rely on the stability of societies or civilizations for thousands of years into the future. It will rely instead on geologic formations that have remained relatively stable for millions of years and on long-lived engineered barriers.

In 2012, the Blue Ribbon Commission again affirmed this basic finding: "The conclusion that disposal is needed and that deep geologic disposal is the scientifically preferred approach has been reached by every expert panel that has looked at the issue and by every other country that is pursuing a nuclear waste management program."[29]

Reflecting the international consensus on this issue, a 2012 report by the Organisation for Economic Co-operation and Development includes a similar statement about deep geological disposal: "It can be made safe for current and future generations; there are no credible alternatives to geological disposal; and, whatever further technical advances may be gained, the need for geological disposal of some classes of waste will persist. Geological disposal also represents an ethically correct approach (taking responsibility within the generation producing the waste) and it should be pursued now proportionately with each country's situation."[30]

Though there is widespread agreement about the need for a geological repository, the approaches taken to siting and developing a repository—in the United States and elsewhere—have been anything but uniform. Managing and disposing of spent nuclear fuel and high-level radioactive waste poses a series of complex and multidimensional challenges. While certain technical aspects of developing a geologic repository would be similar across a wide range of settings, many other issues to be resolved in siting and developing such a facility would be contingent on specific social and political conditions, locally and nationally.

HOW MINED GEOLOGIC DISPOSAL WOULD WORK

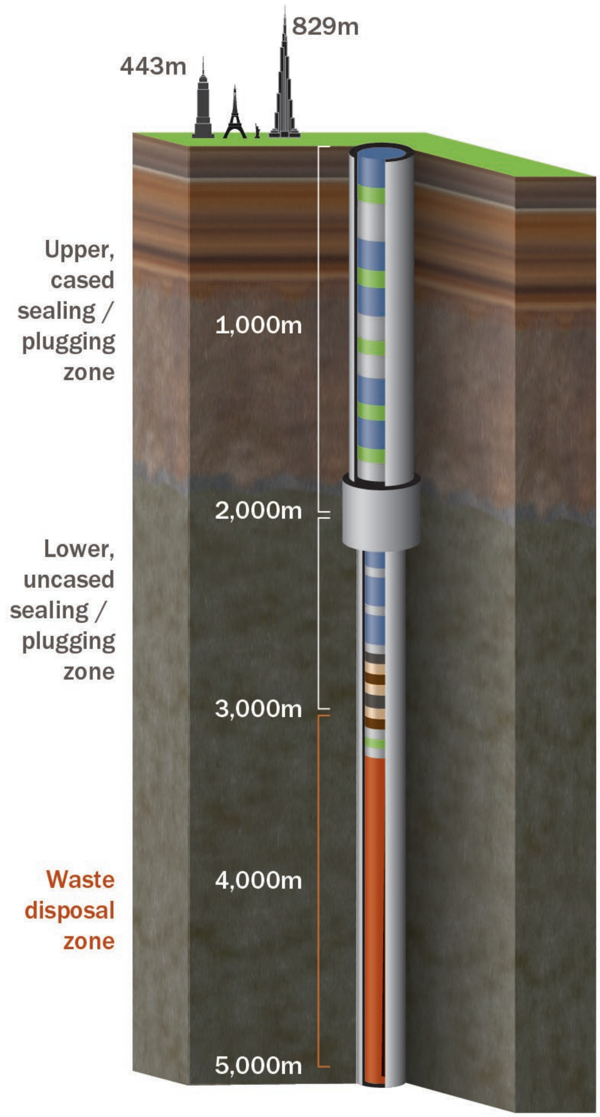
Mined geologic disposal involves placing carefully prepared and packaged radioactive waste in excavated tunnels in geologic formations such as salt, hard rock, or clay. A series of barriers, natural and engineered, would be designed to contain the waste for thousands of years. The chemical and physical forms of the waste, the packages that contain the waste, other engineered barriers, and the natural characteristics of the repository site could all function as barriers in the overall design.

All countries that are pursuing geologic disposal are taking the multi-barrier approach, though they differ in the barriers they emphasize. A German disposal concept, for example, relies heavily on a geologic barrier, the rock salt formation at the prospective disposal site. This is also the case at the existing U.S. disposal facility for transuranic wastes, the Waste Isolation Pilot Plant in New Mexico. Repository designs developed by the nuclear waste management authorities in Sweden and Finland, by contrast, rely heavily on thick copper packages, emplaced in a stable and compatible geologic environment, to contain waste.

DOE is supporting research and development activities at the national laboratories, universities, and in the private sector to address issues relevant to the design and performance of repositories in various media. DOE is also engaging with counterparts from many other countries in international collaborative research activities that provide a valuable resource for ongoing domestic waste management efforts.

BOREHOLE DISPOSAL

An alternative approach to geological disposal that holds promise, but has not yet been fully explored, involves placing radioactive waste in deep boreholes. Boreholes would be drilled to a depth of approximately three miles, with at least two miles of depth penetrating hard rock. Waste packages would be emplaced in the bottom mile or so of a borehole, and the hole would then be filled and sealed. Deep boreholes may offer a viable additional disposal option, particularly for smaller waste forms. Preliminary evaluations of deep borehole disposal indicate a high potential for robust isolation of the waste, and the concept could offer a pathway for earlier disposal of some wastes than might be possible in a mined repository. Consistent with a recommendation of the Blue Ribbon Commission, DOE plans to conduct field tests to evaluate the technical feasibility of emplacing packages of non-radioactive material in boreholes of the required depth.



For more information or to join the conversation on consent-based siting, please visit energy.gov/consentbasedsiting or email the Department at consentbasedsiting@hq.doe.gov.

ENDNOTES

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2. Carter, J. and Dennis Vinson, "Nuclear Fuels Storage and Transportation Planning Project Inventory Basis," FCRD-NFST-2013-000263 rev. 1, June 16, 2014. Table 2-24. Accessed at https://curie.ornl.gov/system/files/NFST%20Inventory%20Rev%201%20%28final%29%206-16-20140.pdf on 11/30/2015.
3. Blue Ribbon Commission on America's Nuclear Future, Report to the Secretary of Energy. January 2012. http://energy.gov/sites/prod/files/2013/04/f0/brcfinalreportjan2012.pdf., p. 16.
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5. Testimony of Energy Secretary Moniz at the Hearing of the Environment and the Economy Subcommittee of the House Energy and Commerce Committee on "Oversight of DOE's Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste," Wednesday, July 31, 2013.
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9. In February 2015, Waste Control Specialists (WCS), a private company, announced plans to apply for an NRC license to develop a storage facility for spent fuel near Andrews, Texas. The proposal has won support from some state and local leaders. In New Mexico, the Eddy-Lea Energy Alliance has likewise indicated interest in developing a consolidated storage facility.
10. It is worth noting that the Nuclear Waste Policy Amendments Act of 1987 included some elements of a consent-based approach. For example, there were efforts in the late 1980s and early 1990s to find a voluntary host site for a monitored retrievable storage (MRS) facility for spent nuclear fuel and high-level radioactive waste. In particular, the 1987 Nuclear Waste Policy Act Amendments established the Office of the Nuclear Waste Negotiator and offered unspecified financial considerations to attempt to win voluntary support for an MRS site in the 1990s. The effort succeeded in eliciting some expressions of interest from a number of Tribes and communities, but the Office of the Nuclear Waste Negotiator was closed after less than five years and none of these expressions of interest were further explored by the government. (Note that a private consortium did pursue expressions of interest from the Mescalero and Goshute Tribes, which eventually led to a proposal for a private storage facility on Goshute land.)
11. U.S. Department of Energy, Strategy for the Management of Used Nuclear Fuel and High-Level Radioactive Waste, January 2013, p. 9.
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18. This does not mean, however, that the savings associated with moving spent fuel from shutdown reactor sites would quickly cover the costs of developing and operating a consolidated storage facility. In fact, a recent DOE study suggests that the "payback" time for moving spent fuel from shutdown sites could be on the order of decades.
19. Speech given by Energy Secretary Ernest Moniz: "A Look Back at the Blue Ribbon Commission on America's Nuclear Future," at the Bipartisan Policy Center, March 24, 2015, Washington D.C. http://energy.gov/articles/secretary-monizs-remarks-look-back-blue-ribbon-commission-america-s-nuclear-future.
20. Ibid.
21. Dry storage systems are licensed by the NRC as Independent Spent Fuel Storage Installations or ISFSIs.
22. The cooperative demonstration program was established by provisions of the Nuclear Waste Policy Act. Electric Power Research Institute, High Burnup Dry Storage Cask Research and Development Project Final Test Plan, February 27, 2014, p. 1-5.
23. Source: NRC website accessed 10/6/2015 http://pbadupws.nrc.gov/docs/ML1524/ML15240A058.pdf updated 8/15/2015. The figure includes operating and shutdown reactor sites with either a general or site-specific license.
24. Jones, R.H. "Dry Storage Cask Inventory Assessment," FCRD-NFST-2014-000602 rev 1, August 31, 2015. Table 4.1-1, p. 12.
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26. Ibid., Table 4.2-1 updated to remove away from reactor storage site at the Idaho National Laboratory (DOE INEEL).
27. Ibid., Table 4.2-1 (p. 14), Table 4.3.1 (p.20), and Table 4.4-1 (p.23).
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