Lessons Learned from National Deep Geologic Repository Programs

Presented to: **High Level Radioactive Waste Committee & WIPP Transportation Technical Advisory Group**

Presented by:

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November 5, 2026
San Diego, CA

Disclaimer:

The views in this presentation do not represent those of the U.S. Nuclear Waste Technical Review Board (Board), except where Board documents are directly quoted. The Board is a federal agency charged with evaluating the technical and scientific validity of the U.S. Department of Energy's (DOE's) efforts to implement the Nuclear Waste Policy Act (NWPA), as amended.

Presentation Topics

- Introduction to U.S. Nuclear Waste Technical Review
- Learning from national repository programs
- Lessons learned from national deep geologic repository programs: Board observations from the June 9, 2026, meeting
- Other relevant Board reviews
- Summary and looking ahead

Federal Agency

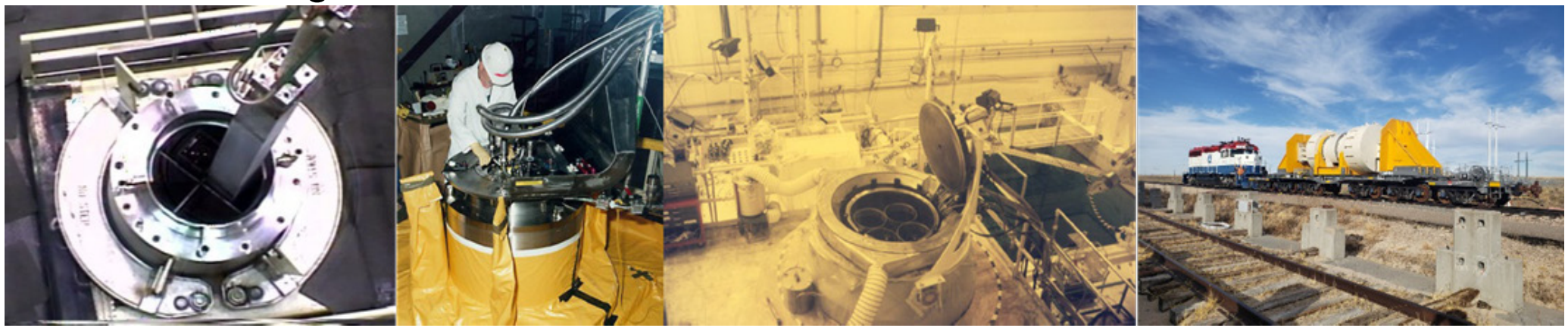
The U.S. Nuclear Waste Technical Review Board (Board) was established by Congress in the Nuclear Waste Policy Amendments Act of 1987 as an establishment within the executive branch






Board Mission

- The Board evaluates the “technical and scientific validity” of U.S. Department of Energy (DOE) activities related to implementing the Nuclear Waste Policy Act
- These DOE activities include:
  - “Packaging or transportation of high-level radioactive waste or spent nuclear fuel”
- Site characterization, design, and development of facilities for disposing of spent nuclear fuel or high-level radioactive waste



Board Members

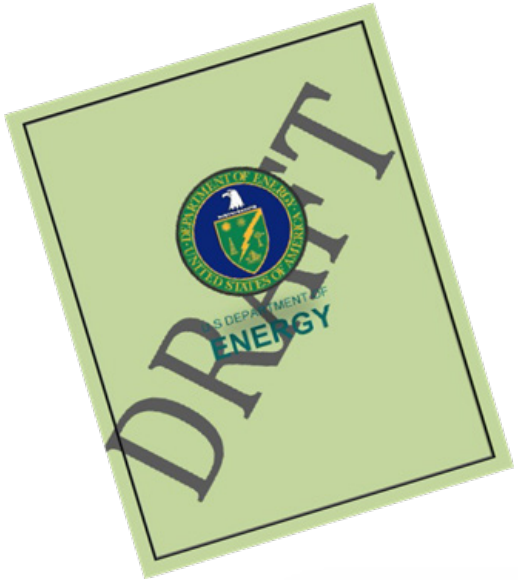


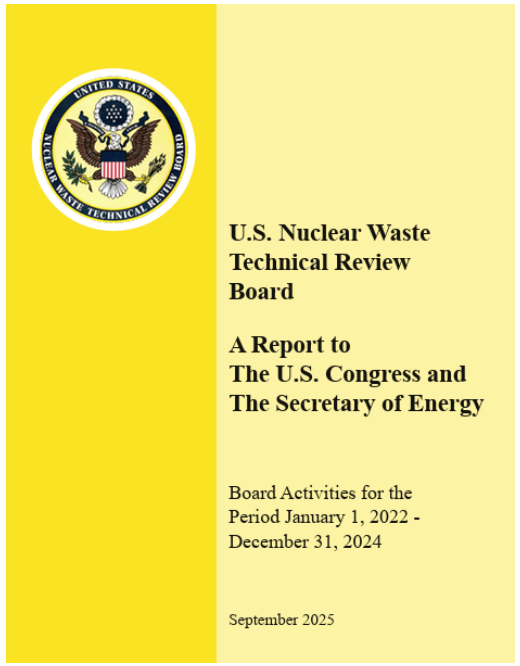


At full strength, the Board has eleven members:

- Candidates nominated by National Academy of Sciences solely on
  - Eminence in a field of science or engineering
  - Established records of distinguished service
- Appointed by the President
- Serve part time in four-year, staggered terms
- May serve until replaced
- Peter Swift, Ph.D., Chair
- Supported by permanent, full-time staff

About the Board



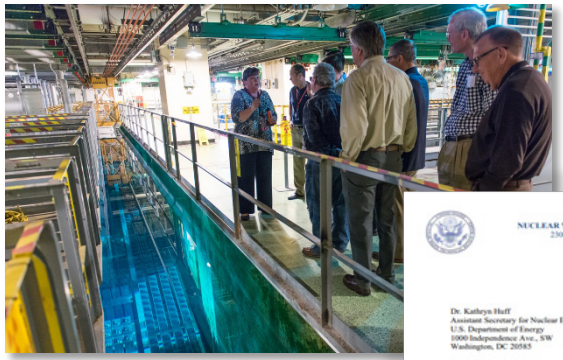


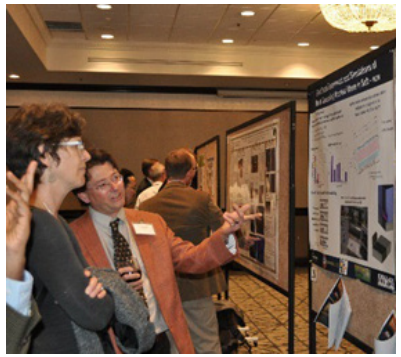


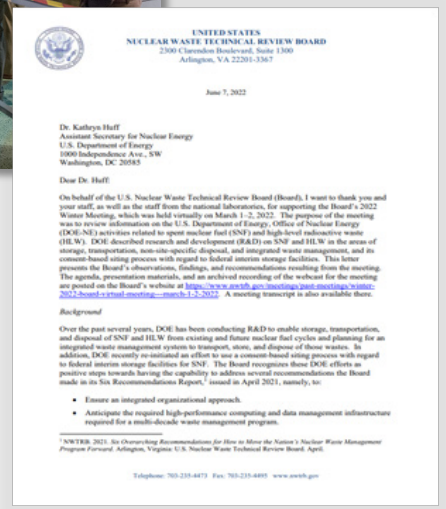
- Conducts independent and objective peer review of DOE activities
- Required to report its findings, conclusions, and recommendations to the U.S. Congress and the Secretary of Energy
- By law, has access to draft DOE documents – allows Board recommendations to be made during decision-making, not after the fact
- Provides congressional testimony at the invitation of Congress

About the Board (cont.)









UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

June 7, 2022

Dr. Kathryn Huff
Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Dr. Huff:

On behalf of the U.S. Nuclear Waste Technical Review Board (Board), I want to thank you and your staff, as well as the staff from the national laboratories, for supporting the Board's 2022 Winter Meeting, which was held virtually on March 1–2, 2022. The purpose of the meeting was to review information on the U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) activities related to spent nuclear fuel (SNF) and high-level radioactive waste (HLW). DOE described research and development (R&D) on SNF and HLW in the areas of storage, transportation, non-site-specific disposal, and integrated waste management, and its consent-based siting process with regard to federal interim storage facilities. This letter presents the Board's observations, findings, and recommendations resulting from the meeting. The agenda, presentation materials, and an archived recording of the webcast for the meeting are posted on the Board's website at https://www.nwtrb.gov/meetings/past-meetings/winter-2022-board-virtual-meeting---march-1-2-2022. A meeting transcript is also available there.

Background

Over the past several years, DOE has been conducting R&D to enable storage, transportation, and disposal of SNF and HLW from existing and future nuclear fuel cycles and planning for an integrated waste management system to transport, store, and dispose of those wastes. In addition, DOE recently re-initiated an effort to use a consent-based siting process with regard to federal interim storage facilities for SNF. The Board recognizes these DOE efforts as positive steps towards having the capability to address several recommendations the Board made in its Six Recommendations Report,[1] issued in April 2021, namely, to:

- Ensure an integrated organizational approach.
- Anticipate the required high-performance computing and data management infrastructure required for a multi-decade waste management program.

[1] NWTRB. 2021. *Six Overarching Recommendations for How to Move the Nation's Nuclear Waste Management Program Forward*. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. April.

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- Holds public meetings and associated site visits at different locations in the United States
- The meetings are webcast
- Provides technical and scientific comments in letters or reports to DOE following public meetings
- Makes all official documents (meeting transcripts and materials, reports, correspondence, congressional testimony, etc.) available on its website: www.nwtrb.gov

Need for a US National Repository

"Finding: The nation needs one or more deep geologic repositories for permanent disposal of domestic spent nuclear fuel and high-level radioactive waste."

"Recommendation: The Board recommends that the Department of Energy take the steps necessary, working with Congress as needed, to create a workable pathway to site, license, construct, and operate a geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste."

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

March 18, 2025

The Honorable Mike Johnson
Speaker of the House
United States House of Representatives
Washington, DC 20515

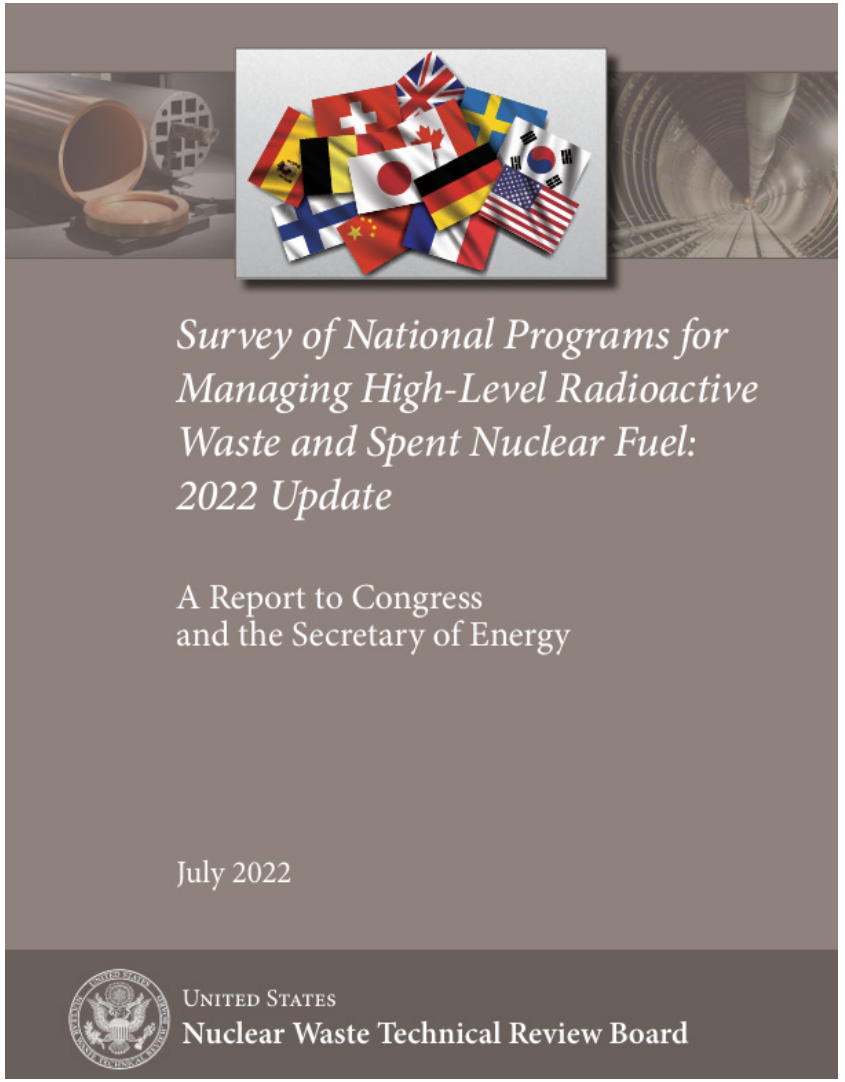
The Honorable Chuck Grassley
President Pro Tempore
United States Senate
Washington, DC 20510

The Honorable Christopher Wright
Secretary
United States Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Speaker Johnson, Senator Grassley, and Secretary Wright:

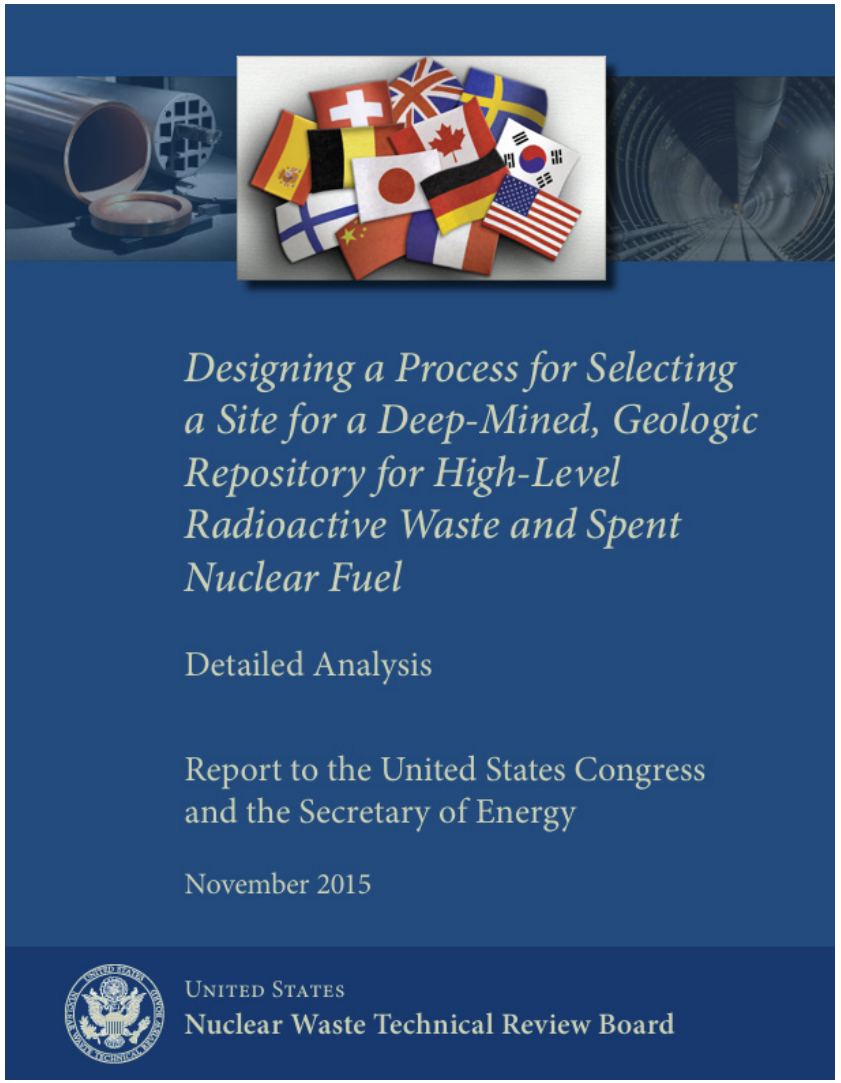
National Repository Programs

- The Board learns from other national repository programs
  - Surveys
  - Board meetings
  - Detailed analyses
  - Visiting and hosting representatives
  - Status of national programs
- Reports to Congress and the Secretary of Energy

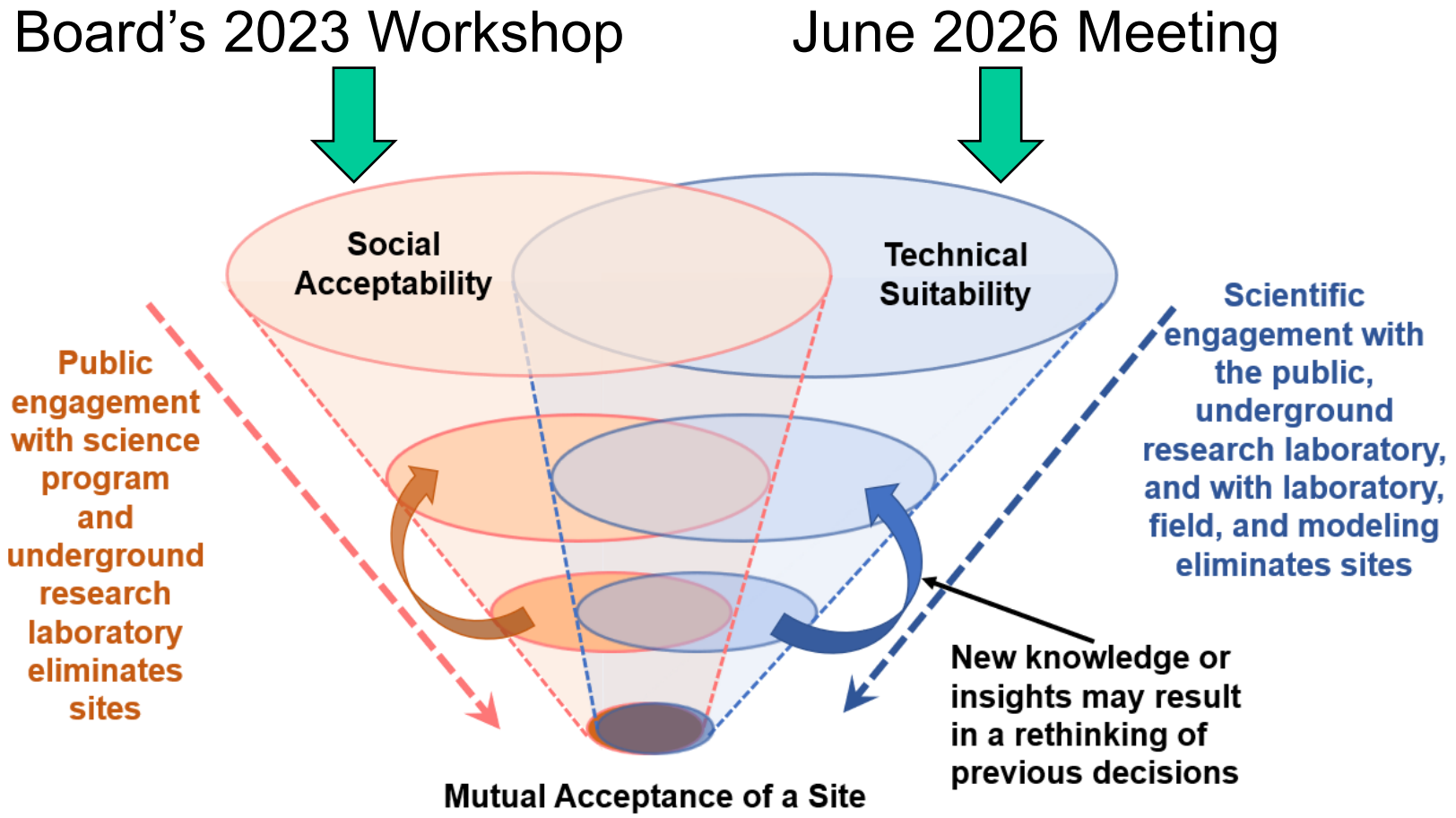


Board Reports on Repository Siting

- 2015 Board report analyzed two dozen siting efforts over the last fifty years in ten nations
  - Canada, China, Finland, France, Germany, Japan, Sweden, Switzerland, United Kingdom, and the United States
  - Siting of a repository requires a socially acceptable siting process and a technical suitable site
- Proceedings of the Board's 2023 International Workshop on Siting of Radioactive Waste Facilities



Focusing on Technical Lessons Learned



Development of a convergent pathway for siting a geologic repository

[revised from Figure 4-3 in *Six Overarching Recommendations for How to Move the Nation's Nuclear Waste Management Program Forward* Report]

- Lessons from siting
  - Republic of Korea
  - Japan
  - Czech Republic
  - Germany
- Post-siting lessons
  - Finland
  - Switzerland

Why the Board Convened the Meeting

- **The United States is in the opening stages of a siting process, following DOE's January 2026 request for information on Nuclear Lifecycle Innovation Campuses**
  - The Board examined lessons from other national programs to inform a workable pathway for permanent disposal.



Synopsis

International experience points to a small set of recurring technical conditions for repository program progress.

Capacity

Plan disposal solutions for the total existing and projected inventory.

Capability

Build organizational, safety, licensing, and systems capacity early.

Durability

Use clear institutions, phased decisions, and continuous learning.

Six Programs Across the Repository Lifecycle

Republic of Korea

Early siting approach

Germany

Down selecting from a white map

Many potential host rock types

Japan

Literature surveys

Selection criteria address hazards

Czech Republic

Four potential sites

Switzerland

Site selected

Transitioning to licensing

Finland

Preparing to operate

Five Common Lessons

1	**Sufficient disposal capacity**	Address current and future inventories.
2	**Early organizational capacity**	Build tools and processes for siting, licensing, and implementation.
3	**Robust framework**	Clarify institutions, roles, and decisions before starting or restarting.
4	**Phased adaptability**	Reassess and change as knowledge and experience grow.
5	**Safety from the outset**	Prepare the implementer to become a licensee and engage stakeholders.

Board Observation 1: Plan for the Total Inventory

"The full set of disposal solutions pursued by DOE should address the total inventory of spent nuclear fuel and high-level radioactive waste, including existing and future inventories."



The Board reiterates that one or more deep geologic repositories will be required.

Board letter to Ted Garrish (July 24, 2026)

Reprocessing/Recycling

Waste Inventory

"almost all existing spent nuclear fuel has no plausible pathway for reuse." (Board 2025 and 2026)

Capacity

World-wide reprocessing operating capacity is about the same as U.S. production rate of spent nuclear fuel.

Repository needed

Existing commercial spent nuclear fuel (>95,000 MTHM; Banerjee and Gadey 2025)

Defense wastes

"approximately 98 percent of the [then-existing] total current inventory of commercial used nuclear fuel by mass can proceed to permanent disposal without the need to ensure post-closure recovery for reuse" (DOE 2013)

"Recycling in any potential future alternative fuel cycle would likely be designed and optimized for the material needs of the associated reactor fleet based on the current and projected [used nuclear fuel] discharges and inventory ***at that time*** (emphasis added), rather than [used nuclear fuel] feedstock that is no longer being produced" (Wagner et al. 2012)

Board letter report to Congress and the Secretary (March 18, 2025) **Board letter to Ted Garrish (July 24, 2026)**

Borehole Disposal Concept

Wastes

Suitable for solidified highly radioactive material from reprocessing of spent nuclear fuel.

“ .. untested

at full scale, and much work remains to be done before the concept can be brought to licensing, if ever.”

Licensing Basis

Nuclear Waste Policy Act (high-level radioactive waste) **or**

Integrated Low Level Radioactive Waste Disposal (proposal)

“… even if borehole disposal can be demonstrated and implemented, it will not obviate the need for mined geologic repositories in the U.S. or other nations that have large inventories of wastes, including some that already exist in configurations that preclude disposal in conventional boreholes without expensive and dose-intensive waste treatment and/or repackaging.”

Board letter report to Congress and the Secretary (March 18, 2025)

Capacity is a Siting Criterion, Not an Afterthought

Waste basis

Define existing and projected inventories that require deep geologic isolation.

Host-rock volume

Evaluate whether candidate geology has sufficient suitable volume and reserve.

System fit

Connect inventory, repository concept, thermal loading, and implementation.

Board emphasis: disposal capacity must be sufficient for the national mission.

Board Observation 2: Build the Implementer Early

Advanced programs report that organizational capacity, tools, and processes should have been established earlier to support siting, licensing, and implementation.

1	**Quality assurance**	Controlled work and evidence
2	**Requirements management**	Traceable design and safety criteria
3	**Licensing support**	Prepare for the implementer's future licensee role
4	**Systems engineering**	Optimize interfaces and the overall system
5	**Continuity**	Sustain data, knowledge, and expertise over decades

The Cost of Waiting

Delaying key safety capabilities often leads to avoidable inefficiencies and delays.

Late Quality Assurance

Evidence must be reconstructed

Late requirements

Design changes lose traceability

Late licensing systems

The organization is not ready for regulatory demands

Late optimization

Major choices constrain later improvements

Board Observation 3: Establish a Durable Framework

A clear and durable framework should guide a program from siting through licensing, construction, operation, and closure.

Establishment of a durable framework will significantly improve the technical and scientific aspects of an integrated nuclear waste management program.



Board Observation 4: Use Phased, Adaptable Development



Screen	Narrow	Investigate	License	Implement
Nationwide or broad-area evaluation	Apply exclusion and comparative criteria	Collect progressively detailed site data	Develop and defend the safety case	Construct, operate, and improve

Change is expected. The program should periodically assess and adapt as evidence, design, and experience grow.

Board Observation 5: Put Safety First and Keep It Central

Siting Criteria

Selection/exclusion criteria

Design

Align engineered barriers and geology



Licensing

Prepare credible evidence

Dialogue

Support regulator and stakeholder interactions

Underground Facilities Can Accelerate Learning





(Kuhlman 2020)

Reduce uncertainty

Build confidence in characterization techniques and models.

Test in situ

Evaluate engineered barriers, monitoring, and repository concepts.

Transfer Knowledge

Use equivalent host-rock settings to inform candidate sites and design.

The Board makes no recommendation specific to the U.S. program to construct a new facility at this time.

What the Board's Observations Imply for DOE

1	**Define the mission**	Tie disposal capacity to the total inventory.
2	**Build the institution**	Establish quality assurance, requirements, licensing, systems, and continuity early.
3	**Clarify the pathway**	Use a durable framework with defined roles and decisions.
4	**Develop adaptively**	Use phased evidence, explicit safety criteria, and learning.
5	**Leverage underground knowledge**	Apply relevant global data while retaining early flexibility.

Other Board Reviews Relevant to this Meeting

- Ongoing review of Office Storage and Transportation activities
  - Fact-finding meeting August 13, 2026
  - The Board was encouraged by DOE's progress with the high burnup research cask shipment. (Swift 2026)
- *Management and Disposal of DOE Spent Nuclear Fuel* (Board 2017)
  - Updating in 2027 focusing on activities at Idaho National Laboratory
  - August 19, 2026, site visit to Idaho National Laboratory
- *Preparing for Nuclear Waste Transportation* (Board 2019)
- Evaluation of DOE's high burnup spent nuclear fuel research and development activities (Board 2021)

Summary and Looking Ahead

- The nation needs a durable solution with one or more deep geologic repositories and a capable implementing organization
- Board will continue advising Congress
- Board will continue its ongoing reviews of DOE activities
- Initial planning for a spring 2027 public meeting in Idaho Falls focused on DOE Office of Nuclear Energy, DOE Office of Environmental Management, and DOE Office of Naval Reactors spent nuclear fuel related activities at Idaho National Laboratory