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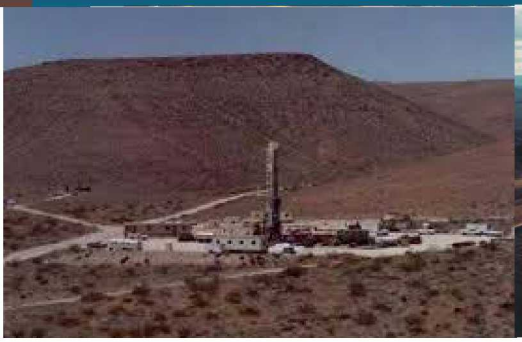
SAND2020-1335PE

Prospects for Permanent Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste in the US



PRESENTED BY

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Outline

- Short history of the US disposal program for spent nuclear fuel and high-level radioactive waste
- Current status of the US program
- Progress world-wide
- Prospects for the US

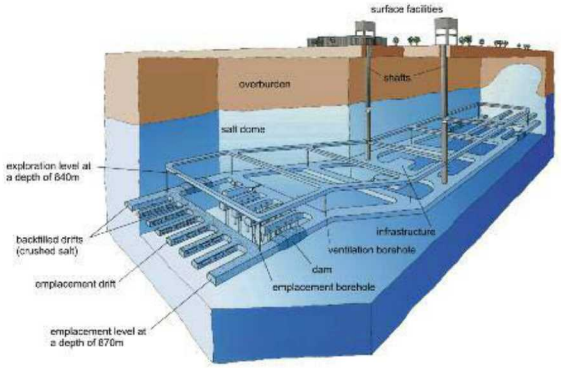
Spent Nuclear Fuel and High-Level Radioactive Waste Disposal: The Goal

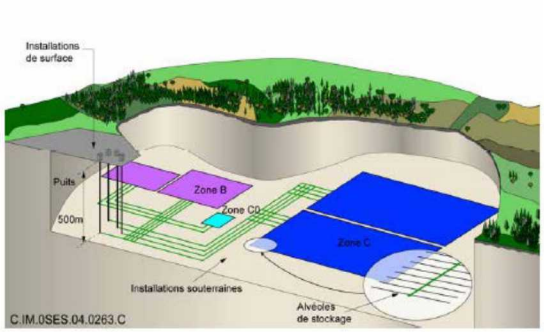
"There has been, for decades, a worldwide consensus in the nuclear technical community for disposal through geological isolation of high-level waste (HLW), including spent nuclear fuel (SNF)."

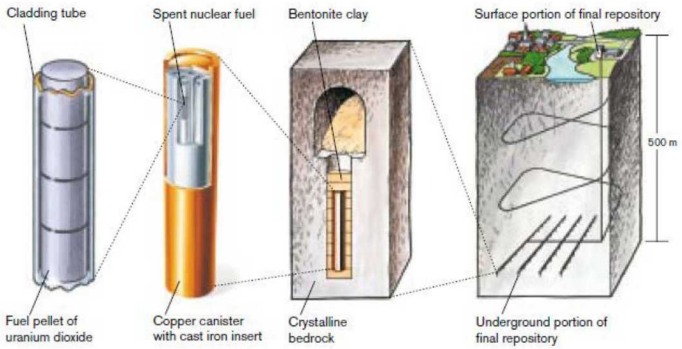
"Geological disposal remains the only long-term solution available."

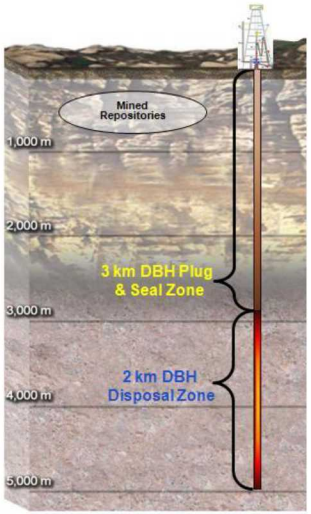
National Research Council, 2001

Deep geologic disposal has been planned since the 1950s

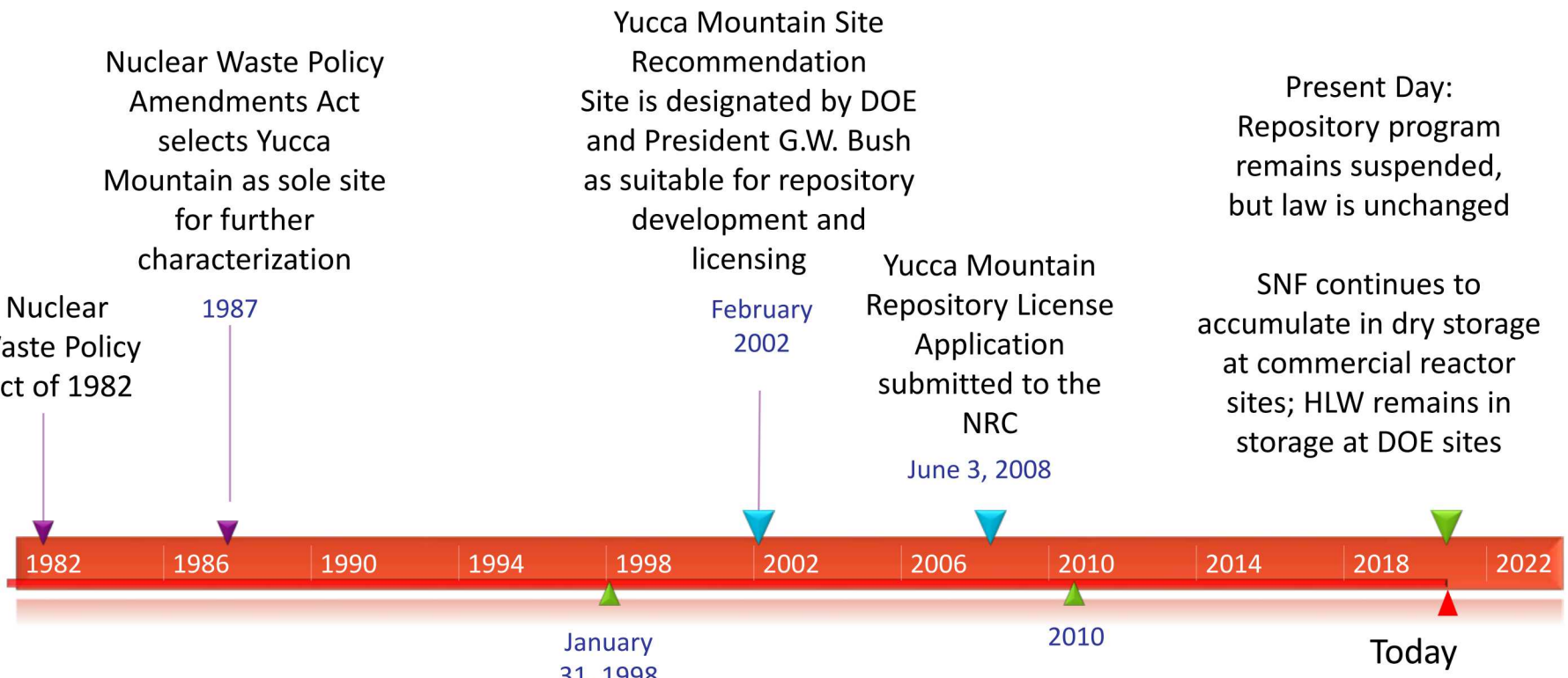








Timeline of the U.S. Repository Program



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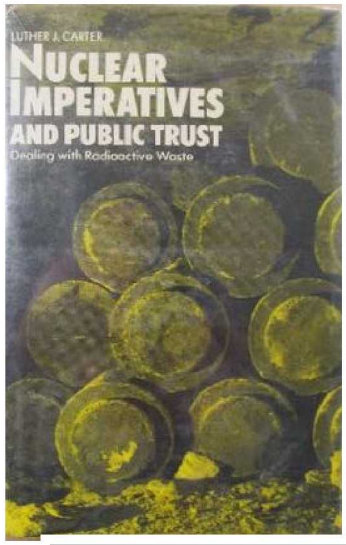
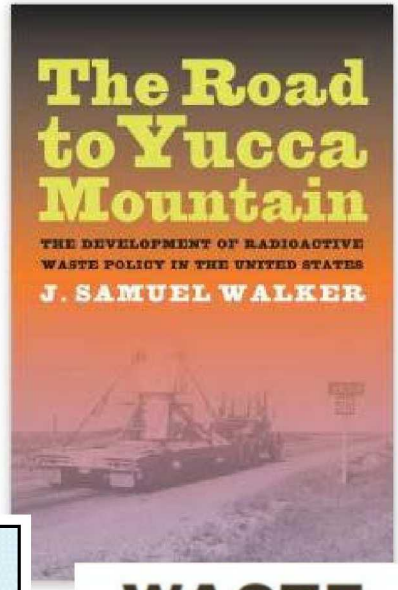
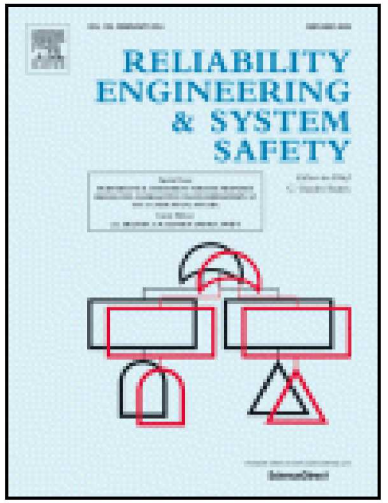
J. Samuel Walker, 2009, *The Road to Yucca Mountain*, Berkeley, CA: University of California Press.

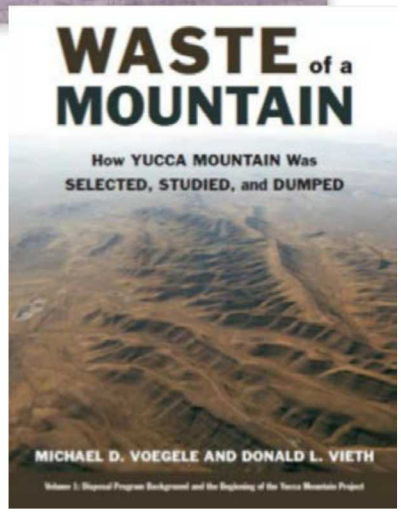
R. P. Rechard, T.A. Cotton, and M.D.Voegele, 2014, "Site Selection and Regulatory Basis for the Yucca Mountain Disposal System for Spent Nuclear Fuel and High-Level Radioactive Waste", *Reliability Engineering and System Safety* v. 122, p. 7-31 [see also other papers in the same volume].

M. D. Voegele and D. L. Vieth, 2016, *Waste of a Mountain: How Yucca Mountain was Selected, Studied, and Dumped,* Nye County Press.







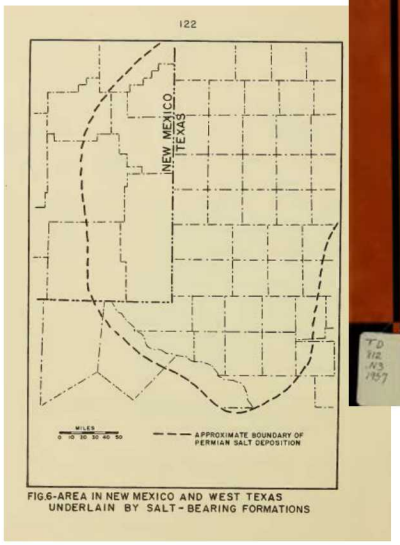


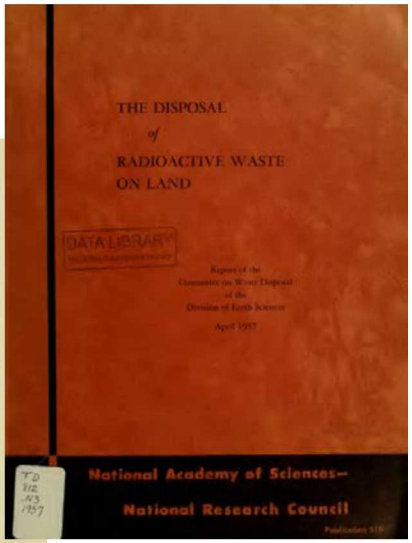
Background

- 1940s: Manhattan Project generates first significant volumes of spent nuclear fuel (SNF) and high-level radioactive waste (HLW)
  - Waste managed on-site
- 1955: National Academy of Sciences (NAS) convenes "Committee on Waste Disposal" at the request of the Atomic Energy Commission (AEC)
- 1957 NAS report *The Disposal of Radioactive Waste on Land*
  - Focus is on disposal of liquid HLW

"Disposal in cavities mined in salt beds and salt domes is suggested as the possibility promising the most practical immediate solution of the problem." (NAS/NRC 1957, p. 1)

"In part of the area a zone of potash salts is present which has been extensively developed near Carlsbad, New Mexico. The zone is about 250 feet thick and contains four workable beds of potash. The lowest bed is the thickest and averages about ten feet in thickness. A large area has been mined out since operations began about 25 years ago. Above the McNutt potash zone is a zone of halite about 500 feet thick, which has been named the Salado." (NAS/NRC 1957, p. 121)





Background (cont.)

- 1960s-1970s: AEC focus on disposal of solidified HLW and SNF in salt mines (Lyons, Kansas followed by Carlsbad, NM)
  - 1969 fire at Rocky Flats focuses attention on transuranic waste
- Early 1970s: recognition of potential suitability of multiple rock types, including granitic and crystalline rocks, salt, shale, and tuff (Schneider and Platt, 1974; Ekren et al., 1974)
- 1976: National policy moves away from reprocessing of commercial SNF

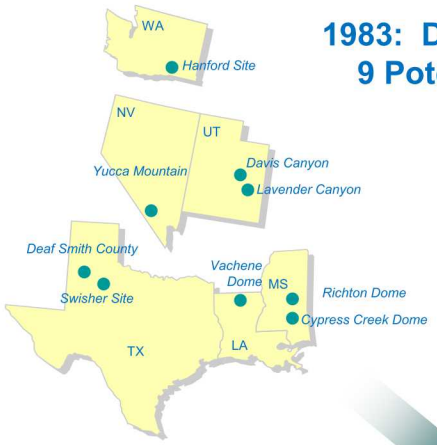
INEEL 2003, Figure 3-8 (INEEL Photo # 69-6138)

- 1980: Department of Energy (DOE) completes "Final Environmental Impact Statement: Management of Commercially Generated Radioactive Wastes" (DOE/EIS-0046F)
  - Formally recommends deep geologic disposal in mined repositories
- 1982: Congress passes the Nuclear Waste Policy Act (NWPA)

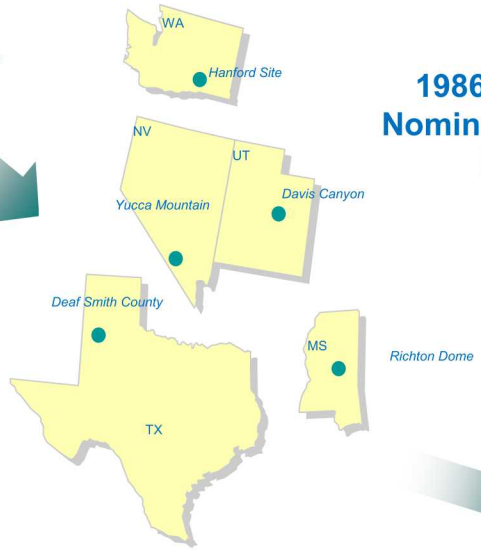
1982-1987: The Siting Process under the NWPA

The NWPA of 1982 (sec. 112) requires
- *The Secretary (DOE) to consult with affected governors and issue siting guidelines*
- *The Secretary to nominate at least 5 sites*
- *The Secretary to recommend 3 sites for characterization*

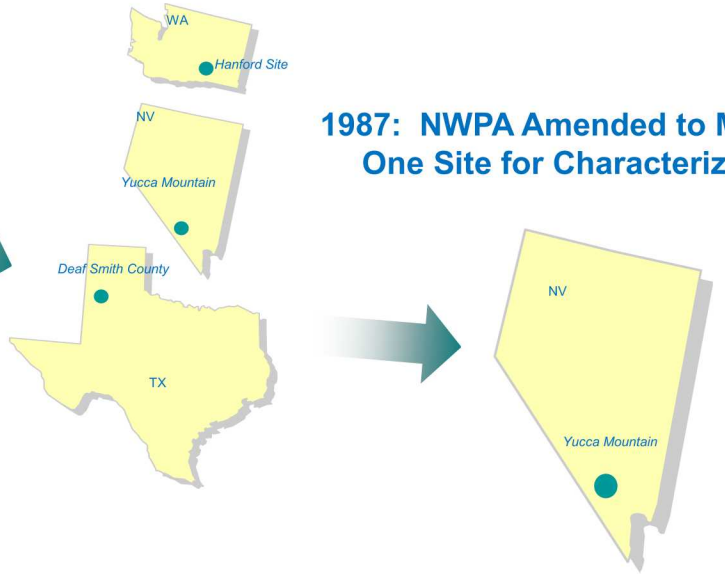
1983: DOE identifies 9 Potential Sites



1986: Secretary of Energy Nominates 5 Sites, 3 Approved for Further Study

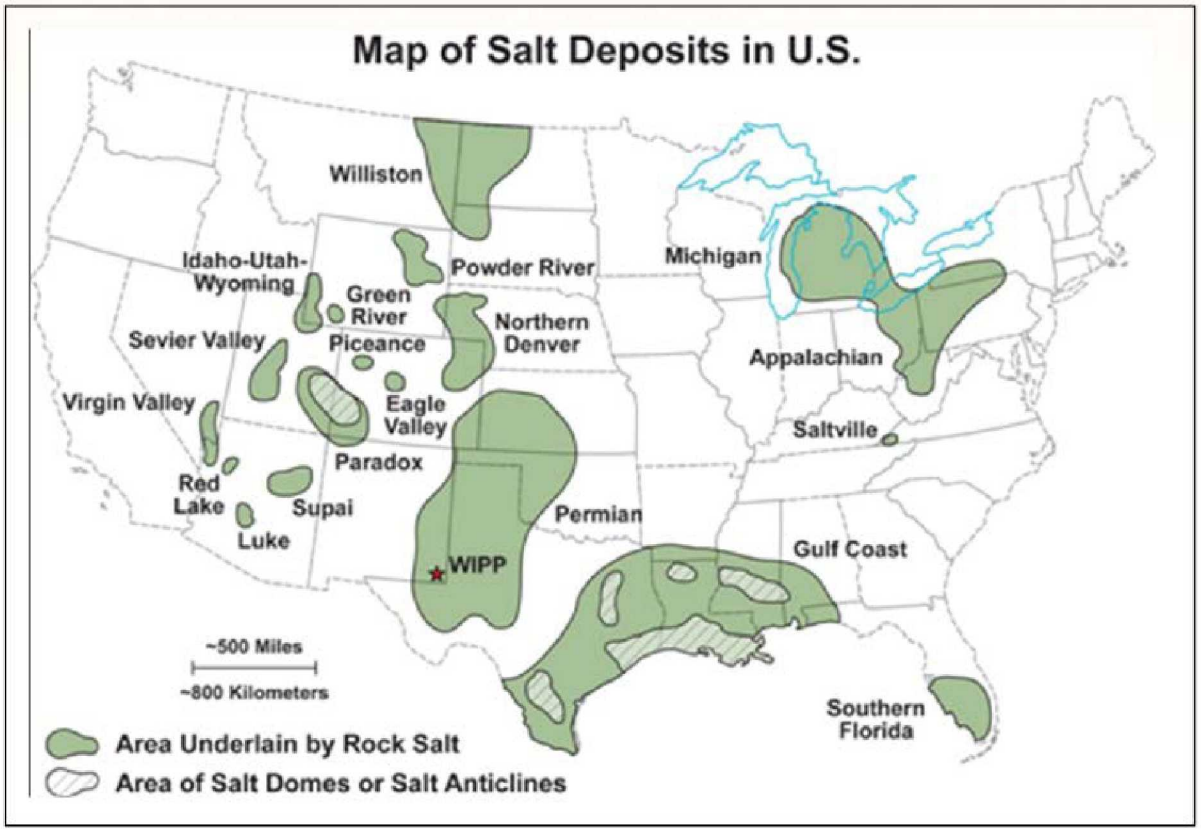


1987: NWPA Amended to Mandate One Site for Characterization



1986 Multiattribute Utility Analysis (DOE/RW-0074) provided input to DOE recommendation (DOE/S-0048) of 3 sites from the 5 that had been nominated

Salt Deposits in the United States

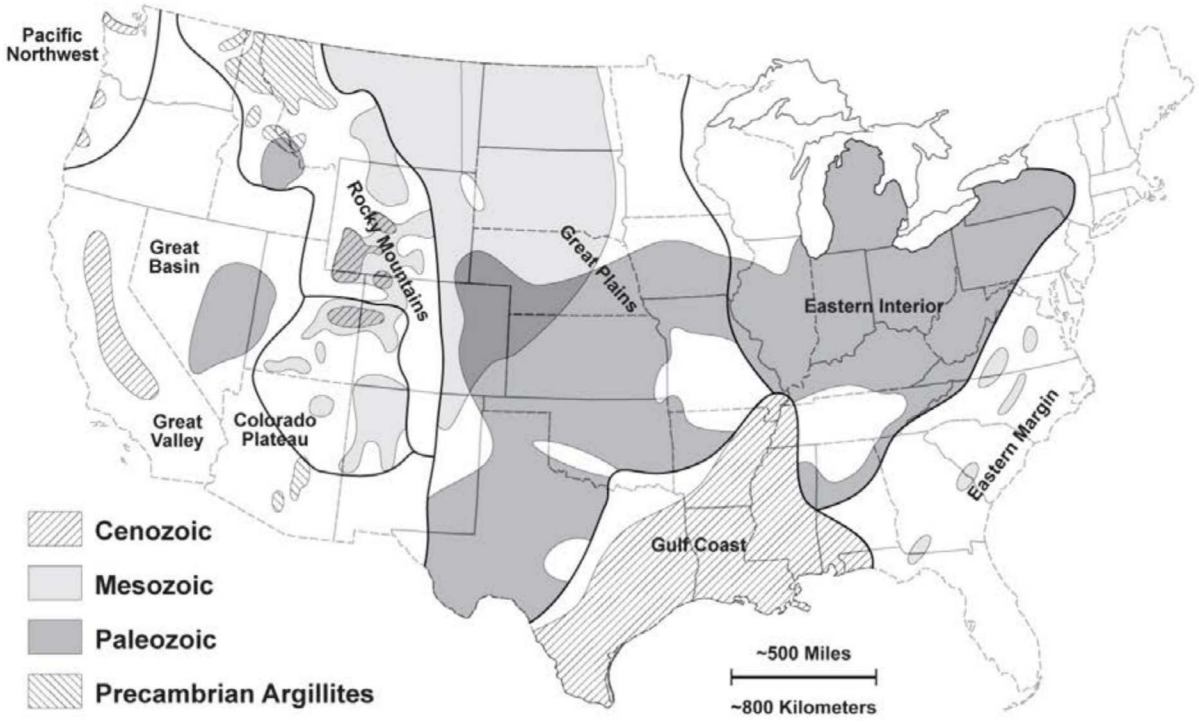


Source: Johnson and Gonzales, 1978, in Hansen and Leigh, 2010

The US had active salt repository investigations for HLW and SNF until 1986 (some heat-generating waste R&D continued at WIPP until 1989)

Significant subsurface investigations at Project Salt Vault (Kansas), Avery Island (Louisiana), and WIPP

Shale Deposits in the United States



Source: Gonzales and Johnson, 1984, in Hansen et al., 2010, see also Croff et al., 2003

The US had active shale repository investigations from the 1970s through 1986

Map includes a range of clay-rich lithologies

- plastic clays
- indurated shales and argillites

Granite Outcrops in the United States

Source: Bush et al. 1976, in Mariner et al. 2011

The US had an active R&D and siting program for a repository in crystalline rock until 1986

Map includes a range of crystalline rock types

The Second Repository Program as of January 1986

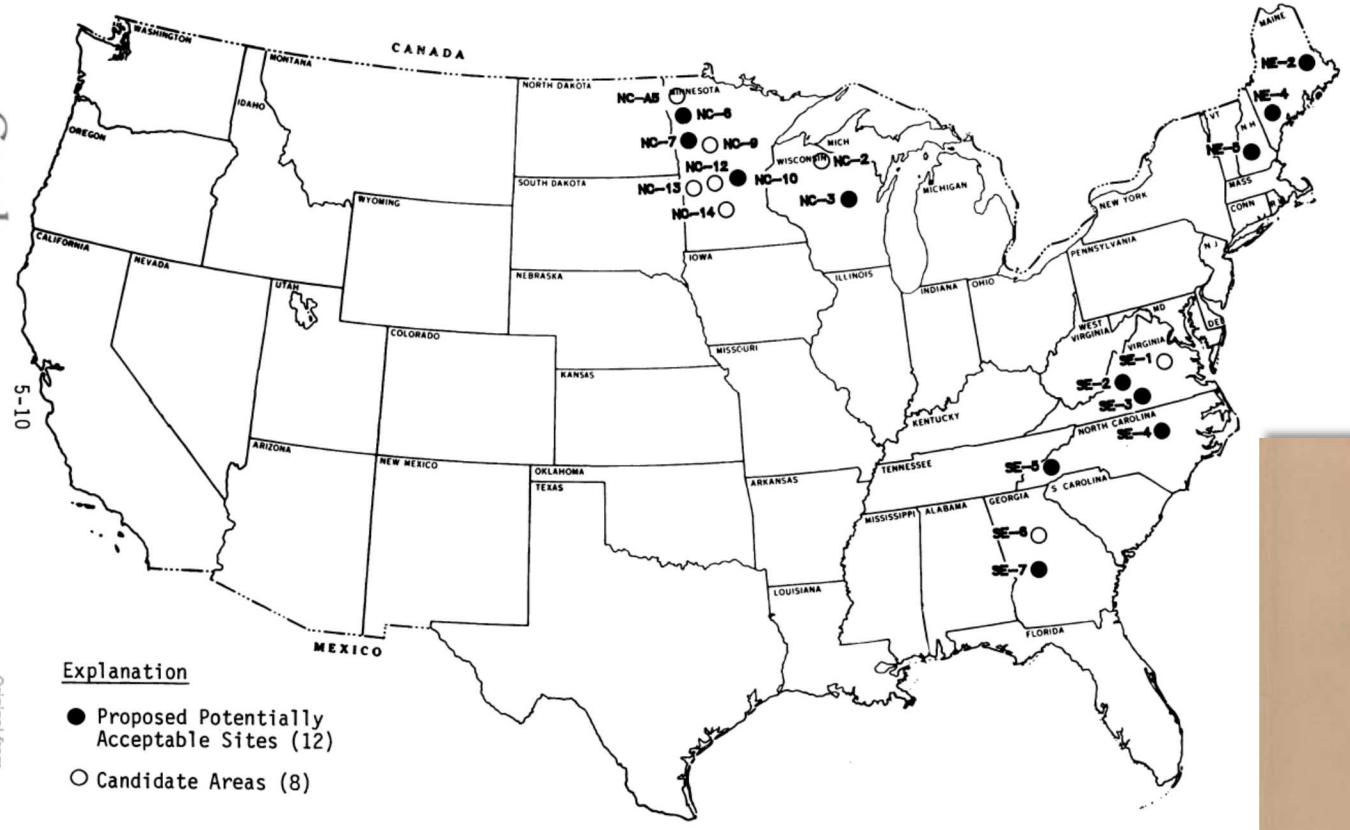
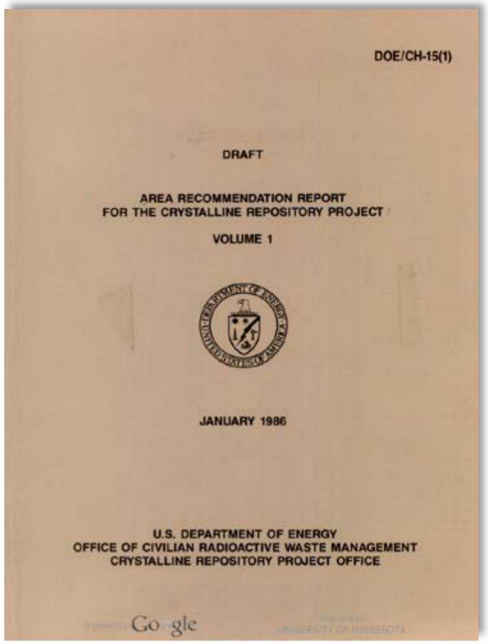


Figure 5-2. Proposed Potentially Acceptable Sites and Candidate Areas for the Second Repository

12 "Potentially Acceptable Sites" and 8 backup "Candidate Areas" identified from detailed review of 235 crystalline rock bodies in 17 states



From DOE 1986, Draft Area Recommendation Report for the Crystalline Repository Project, Volume 1. DOE/CH-15(1), January 1986

Events of 1986 and 1987

May 28, 1986: DOE Secretary John Herrington suspends all work on the Crystalline Repository Project:

- "…the areas identified in the report are no longer under active consideration. No other sites are under consideration" (quoted in Halstead et al., 1988)
- Announcement cites 1) progress on siting the first repository and monitored retrievable storage and 2) lower than anticipated projections of total SNF requiring geologic disposal.

October 1, 1987: DOE Secretary Herrington announces intent to resume work on the Crystalline Repository Project, consistent with NWPA requirements for a second repository

December 21, 1987: Nuclear Waste Policy Amendments Act selects Yucca Mountain as the only site to be characterized for the first repository

- Suspends second repository program
  - "The Secretary may not conduct site-specific activities with respect to a second repository unless Congress has specifically authorized and appropriated funds for such activities"
  - Terminates all ongoing granite research within six months
  - Imposes additional potentially disqualifying siting criteria specific to any future consideration of crystalline rock sites
    - "seasonal increases in population," "proximity to public drinking water supplies," and impacts on tribal lands.
- Requires DOE to report to Congress regarding the need for a second repository no later than January 1, 2010

The 2008 Second Repository Report

DOE/RW-0595 identified three options

- Revise NWPA to remove statutory limit of 70,000 Metric Tons Heavy Metal at Yucca Mountain and dispose of the full inventory of SNF and HLW
- Begin process to site a second repository
- Defer the decision indefinitely and store SNF and HLW

Recommendation to the President and Congress:

- Lift statutory limit on Yucca Mountain capacity and defer decision regarding a second repository

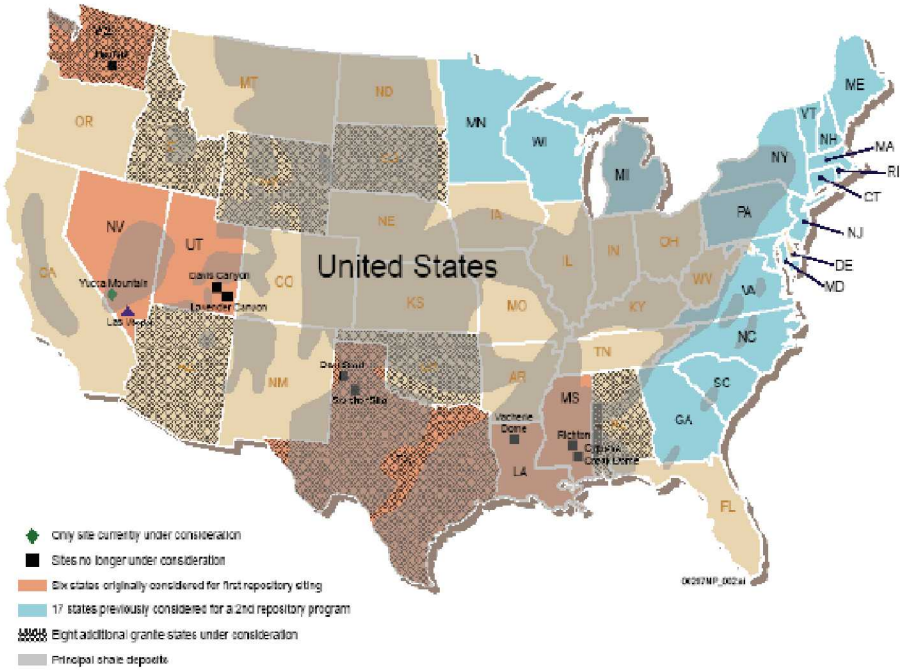


Figure 3 from DOE/RW-0595, summarizing first and second repository candidate states with an overlay of shale formations

2015-2017: DOE's Efforts to Implement a Consent-Based Siting Process

Federal Register notice December 23, 2015 (80 FR 79872) solicits public comment on design of a consent-based siting process for both storage and disposal facilities

Public meetings held in 10 locations throughout 2016

Comments received through July 2016

Draft summary of public input released September 15, 2016

Draft Consent-Based Siting Process released for public comment January 12, 2017

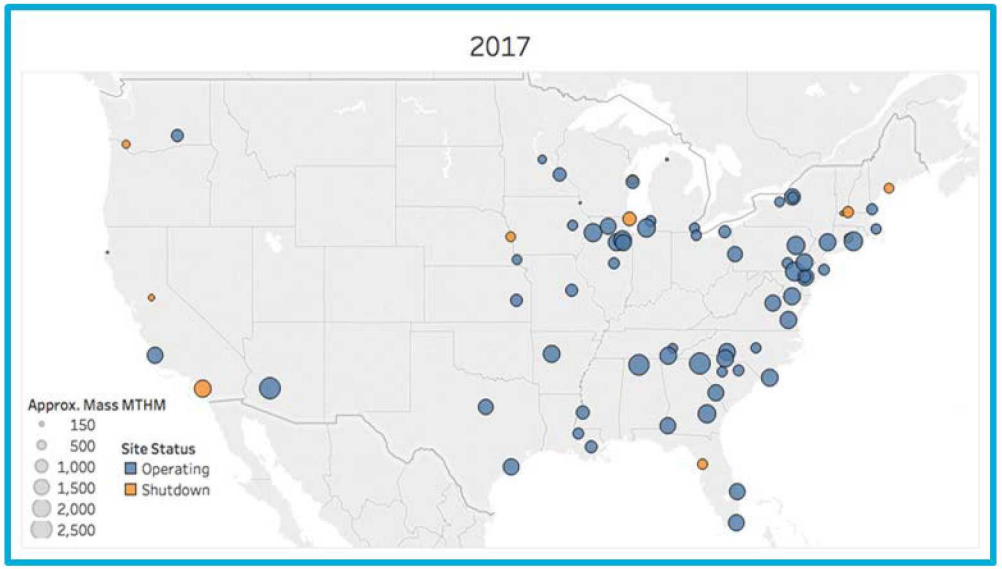
Program terminated in January 2017 by new administration

- Incompatible with the administration's stated goal of resuming Yucca Mountain licensing process
- Incompatible with the Nuclear Waste Policy Act; enabling legislation has not been not forthcoming

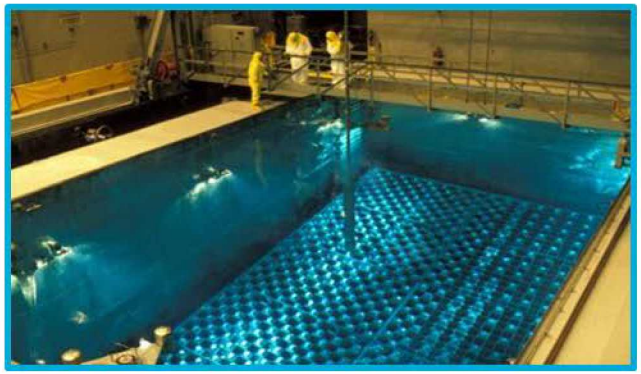
Geologic Disposal in the US: The Reality

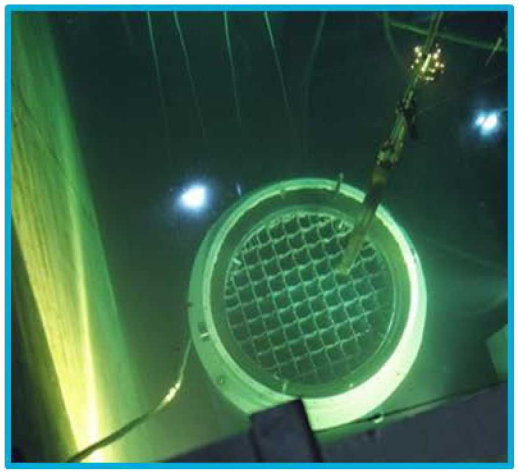
Commercial SNF is in Temporary Storage at 75 Sites in 34 States

- Pool storage provides cooling and shielding of radiation
  - Primary risks for spent fuel pools are associated with loss of the cooling and shielding water
- US pools have reached capacity limits and utilities have implemented dry storage
- Some facilities have shutdown and all that remains is "stranded" fuel at an independent spent fuel storage installation (ISFSI)



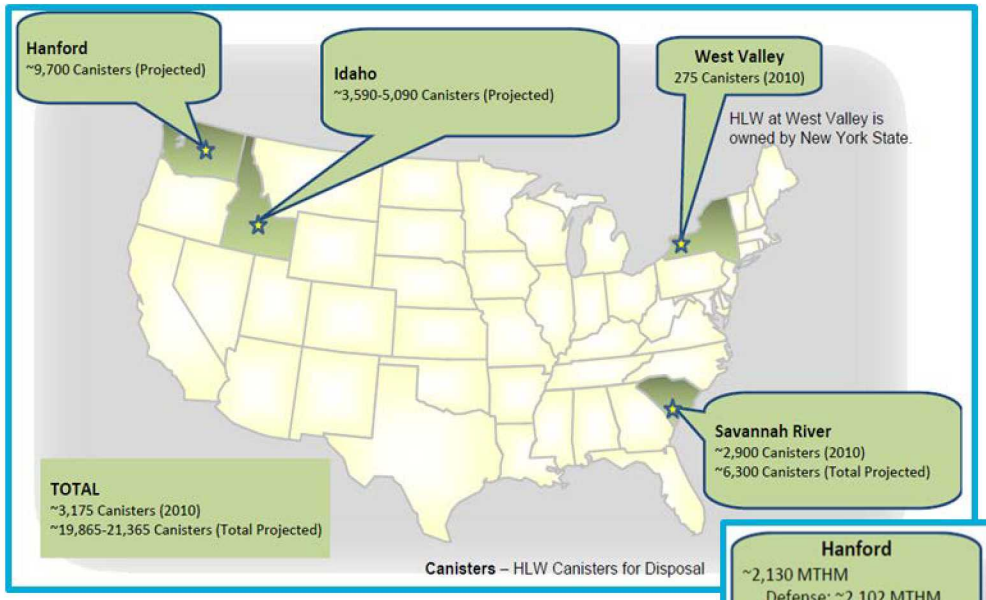
Map of the US commercial SNF storage from Bonano et al. 2018





Geologic Disposal in the US: The Reality (cont.)

DOE-managed SNF and HLW is in Temporary Storage at 5 Sites in 5 States

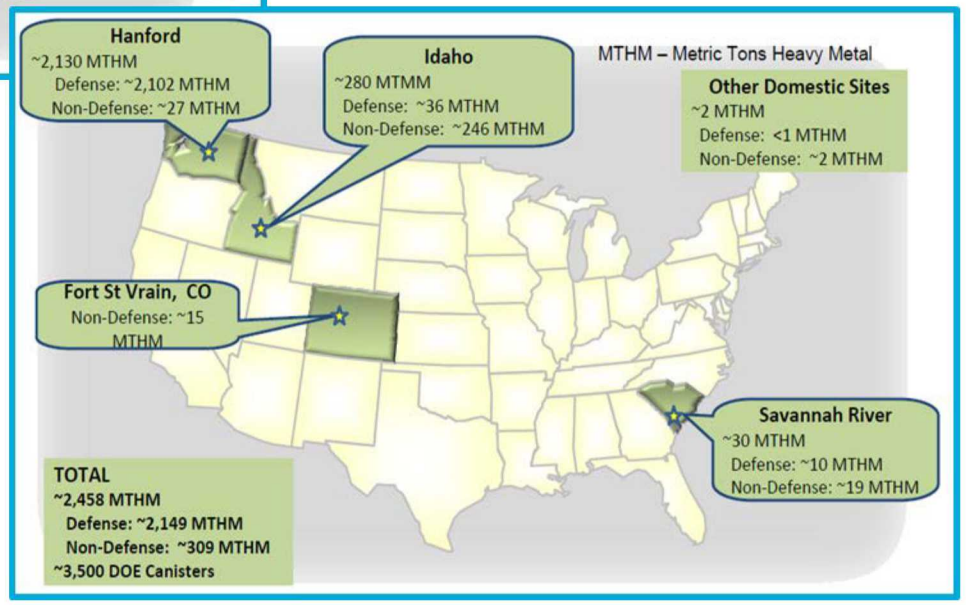


DOE-Managed HLW

~20,000 total canisters (projected)

DOE-Managed SNF

~2,458 Metric Tons



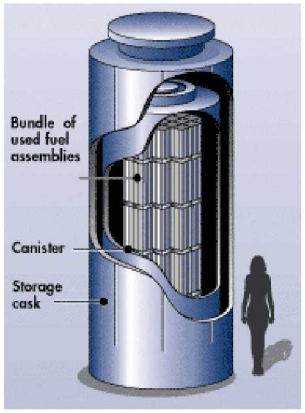
Updated from Marcinowski, F., "Overview of DOE's Spent Nuclear Fuel and High-Level Waste," presentation to the Blue Ribbon Commission on America's Nuclear Future, March, 25, 2010, Washington, DC.

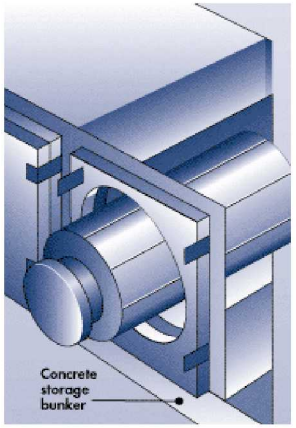
Dry Cask Storage System Terminology

Dry Cask Storage Systems (DCSSs) include:

- Dry cask/canister storage systems using dual purpose canisters (DPCs) that are certified for both storage and transportation (right-hand photographs)
  - The welded stainless steel DPC is placed in a concrete and steel overpack (vertical cask or horizontal bunker) for shielding and protection during storage. The DPC is removed from the storage overpack and placed in a shielded transportation cask for transport.
  - Vertical DPC designs can be above or below grade
- "Bare fuel" casks with bolted lids, integral shielding and no overpack, available in cast iron and forged steel designs (bottom left photograph)
  - Few sites in the U.S. continue to load these systems

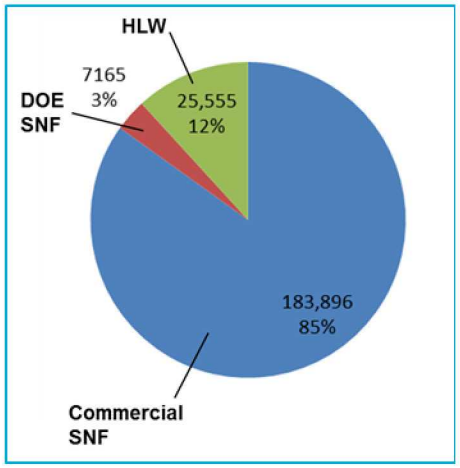
Multiple vendors provide NRC-certified dry storage systems to utilities



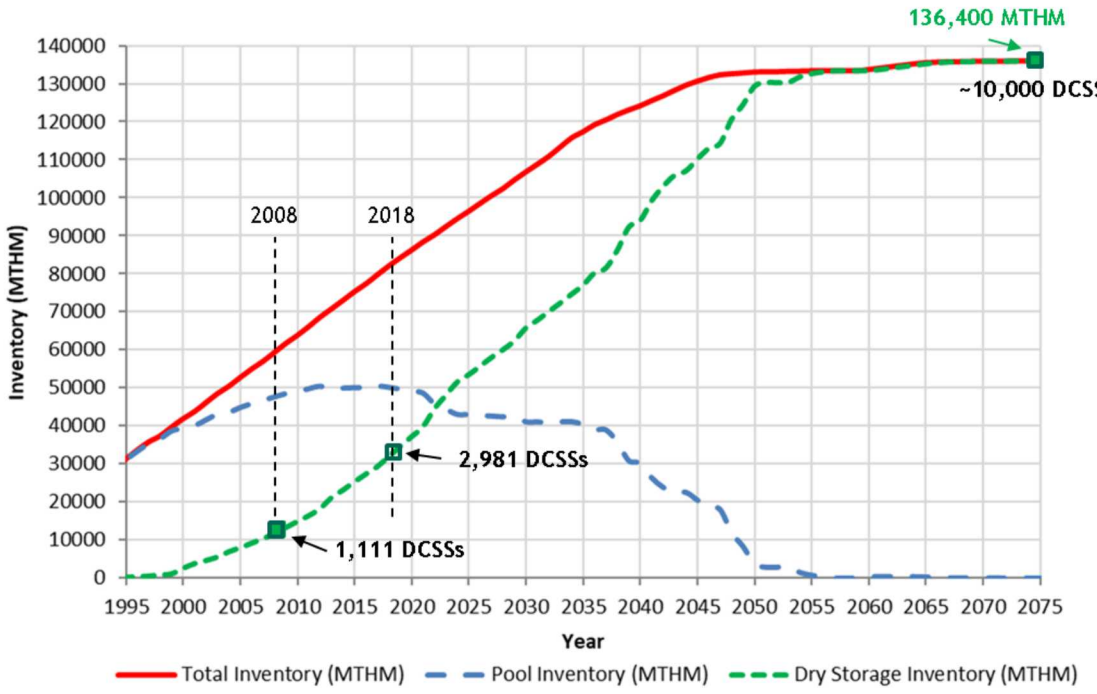


US Projections of SNF and HLW

Projected Volumes of SNF and HLW in 2048



Volumes shown in m³ assuming constant rate of nuclear power generation and packaging of future commercial SNF in existing designs of dual-purpose canisters.



Projection assumes full license renewals and no new reactor construction or disposal (updated from Bonano et al., 2018)

81,518 MTHM (metric tons heavy metal) of commercial SNF in storage in the US as of Dec. 2018

Approx. 30,000 MTHM in dry storage at reactor sites, in 2,981 cask/canister systems as of Dec. 2018

- Balance in pools, mainly at reactors

Approx. 2200 MTHM of SNF generated nationwide each year

- Approximately 160 new dry storage canisters are loaded each year in the US

Observations on Current Practice

- Current practice is safe and secure
  - Extending current practice raises data needs; e.g., canister integrity, fuel integrity, aging management practices
- Current practice is optimized for reactor site operations
  - Occupational dose
  - Operational efficiency of the reactor
  - Cost-effective on-site safety
- Current practice is not optimized for transportation or disposal
  - Thermal load, package size, and package design

Placing spent fuel in dry storage in dual purpose canisters (DPCs) commits the US to some combination of three options

1) Repackaging spent fuel in the future

2) Constructing one or more repositories that can accommodate DPCs

3) Storing spent fuel at surface facilities indefinitely, repackaging as needed

Each option is technically feasible, but none is what was originally planned

After Decades of Repository Science and Engineering, What Do We Have?

- Repository programs in multiple nations
  - Belgium, Canada, China, Czech Republic, Finland, France, Germany, Japan, Korea, Russia, Spain, Sweden, Switzerland, United Kingdom, United States …
- Detailed safety assessments have been published for multiple disposal concepts, e.g.,
  - Switzerland: Opalinus Clay, 2002
  - France; Dossier 2005 Argile, 2005
  - USA: Yucca Mountain License Application for a repository in tuff, 2008
  - Sweden: Forsmark site in granite, 2011
  - Finland: Safety Case for Olkiluoto site in gneiss, 2012
  - Canada: Hypothetical repository in carbonate, 2013
- One deep mined repository has been in operation for transuranic waste (the Waste Isolation Pilot Plant in the US) since 1999

First order conclusions about geologic disposal

- **There are multiple approaches to achieving safe geologic isolation**
- **Estimated long-term doses are very low for each of the disposal concepts that have been analyzed in detail**
- **Safe isolation can be achieved for both SNF and HLW**

Status of Deep Geologic Disposal Programs World-Wide

Nation	Host Rock	Status
Finland	Granitic Gneiss	Construction license granted 2015. Operations application to be submitted in 2020
Sweden	Granite	License application submitted 2011
France	Argillite	Disposal operations planned for 2025
Canada	Granite, sedimentary rock	Candidate sites being identified
China	Granite	Repository proposed in 2050
Russia	Granite, gneiss	Licensing planned for 2029
Germany	Salt, other	Uncertain
USA	Salt (transuranic waste at the Waste Isolation Pilot Plant) Volcanic Tuff (Yucca Mountain)	WIPP: operating Yucca Mountain: suspended

Others: Belgium (clay), Korea (granite), Japan (sedimentary rock, granite), UK (uncertain), Spain (uncertain), Switzerland (clay), Czech Republic (granitic rock), all nations with nuclear power.

Source: Information from Faybishenko et al., 2016

Current Constraints on the US Program

- The Nuclear Waste Policy Act remains the law
  - Permanent disposal of spent nuclear fuel and high-level radioactive waste is a federal responsibility
    - Assigned to the Department of Energy Office of Civilian Radioactive Waste Management
  - Yucca Mountain remains selected by law as the only site to be evaluated
    - "The Secretary may not conduct site-specific activities with respect to a second repository unless Congress has specifically authorized and appropriated funds for such activities." (NWPA Sec. 161(a))
    - The Yucca Mountain project has not been funded since 2010
      - NRC staff completed their Yucca Mountain review in 2015, and found that "the DOE has demonstrated compliance with the NRC regulatory requirements" for both preclosure and postclosure safety
      - The Yucca Mountain licensing process remains suspended, and approximately 300 technical contentions remain to be heard before a licensing board could reach a decision
  - The NWPA constrains federal storage of commercial spent nuclear fuel
    - "Construction of [a federal interim storage facility] may not begin until the Commission has issued a license for the construction of a repository" (NWPA Sec. 148(d)(1))

Additional Considerations

- The Nuclear Waste Policy Act created the Nuclear Waste Fund
  - "to ensure that the costs of carrying out activities relating to the disposal…will be born by the persons responsible for generating such waste and fuel" (NWPA Sec. 111(d)(4)
  - The NWF collected $0.001/kWh from 1983 until 2014 when a US Court of Appeals denied further collection without demonstrated progress
    - Balance of the NWF as of December 2018 was approx. $39 billion, subject to Congressional appropriation
- The Nuclear Waste Policy Act requires DOE to take receipt of commercial spent nuclear fuel beginning not later than January 31, 1998
  - Nuclear Power Utilities have been paid since 1998 by the US Government to store fuel as a result of breach-of-contract settlements
  - These payments come from the US Treasury Department's Judgment Fund, and are not subject to Congressional appropriation

Concluding thoughts: What does the Nation do Next?

Continue Implementing the Nuclear Waste Policy Act?

- Restart licensing for Yucca Mountain?
- Abandon Yucca Mountain and have DOE report to Congress with recommendations for further action?

Amend the Nuclear Waste Policy Act to allow other options?

- Federal management of commercial spent fuel in consolidated interim storage?
- Federal consideration of disposal sites other than Yucca Mountain?
- Private sector management of spent fuel and high-level waste disposal?

Questions to consider

- Who decides basic policy questions?
  - Congress and the Federal Courts
- Who pays?
  - Ratepayers (The Nuclear Waste Fund)
  - Taxpayers (The Judgment Fund)
- What is the role of science in the decision-making process?

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