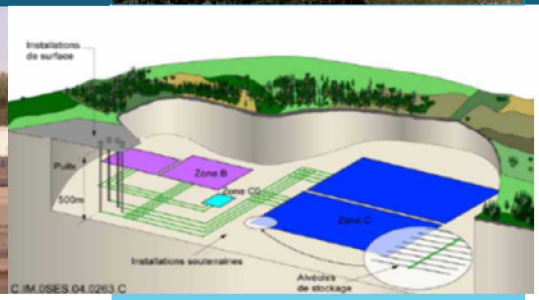
SAND2019-8432C

Status of Back End of the Nuclear Fuel Cycle in the United States of America: Current R&D Program



PRESENTED BY

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Nuclear Energy Fuel Cycle Program

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Outline

- Status of Current System
  - Timeline of US Repository Program
  - Actions over the last decade
  - Accumulation of SNF Inventory
  - Future Options
- Current R&D Program and Priorities
  - Storage & Transportation
  - Disposal
- Concluding Remarks

Timeline of the U.S. Repository Program

1982
Nuclear Waste Policy Act of 1982

1987
Nuclear Waste Policy Amendments Act selects Yucca Mountain as sole site for further characterization

January 31, 1998
DOE fails to open a repository by the statutory deadline

February 2002
Yucca Mountain Site Recommendation Site is designated by DOE and President G.W. Bush as suitable for repository development and licensing

June 3, 2008
Yucca Mountain Repository License Application submitted to the NRC

2010
Obama Administration decides Yucca Mountain is not workable; Project suspended

Spent nuclear fuel continues to be generated at ~2,200 MTHM/yr.

Present Day
Repository program remains suspended, but law is unchanged

SNF continues to accumulate in dry storage at commercial reactor sites; HLW remains in storage at DOE sites

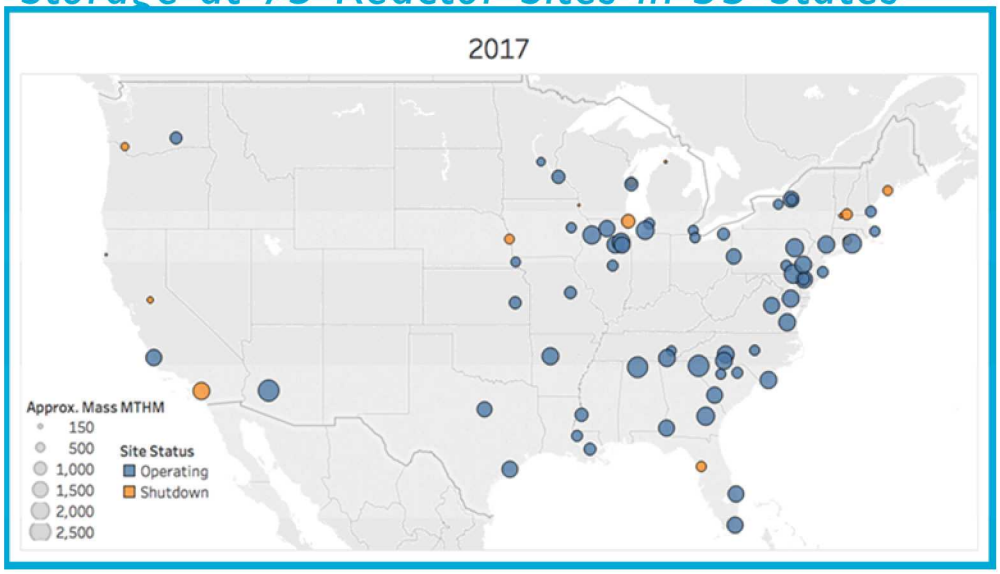
Current Status of the US Program

2008	• Yucca Mountain Repository License Application submitted
2009	• Department of Energy (DOE) determines Yucca Mountain to be unworkable
2010	• Last year of funding for Yucca Mountain project
2012	➉Blue Ribbon Commission on America's Nuclear Future completes its recommendations, including a call for a consent-based process to identify alternative storage and disposal sites
2013	• Federal Court of Appeals orders Nuclear Regulatory Commission (NRC) to complete its staff review of the Yucca Mountain application with remaining funds
2015	•NRC staff completes Yucca Mountain review, finds that "the DOE has demonstrated compliance with the NRC regulatory requirements" for both preclosure and postclosure safety
2015	•DOE begins consideration of a separate repository for defense high-level wastes and initiates first phase of public interactions planning for a consent-based siting process for both storage and disposal facilities. (Both activities terminated 2017.)
2016-18	•Private sector applications to the NRC for consolidated interim storage (Waste Control Specialists [now Interim Storage Partners] in Andrews, TX and Holtec in Eddy/Lea Counties, NM)
2019	•Yucca Mountain licensing process remains suspended, and approximately 300 technical contentions remain to be heard before a licensing board can reach a decision

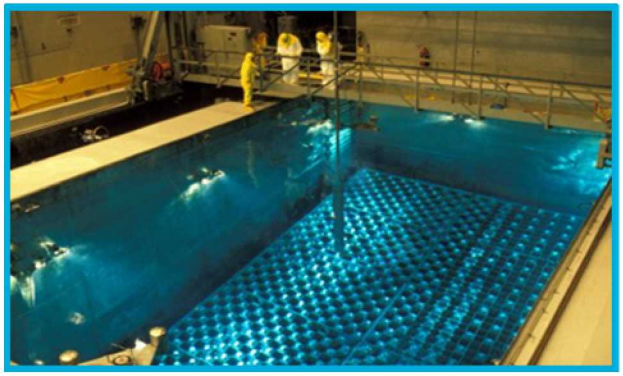
SNF Management in the US: The Reality

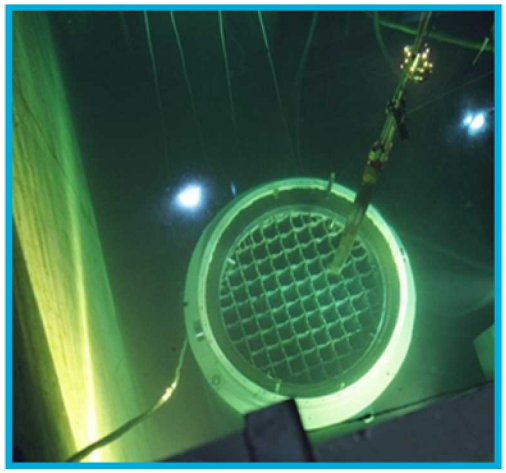
Commercial SNF is in Temporary Storage at 75 Reactor Sites in 33 States

- 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

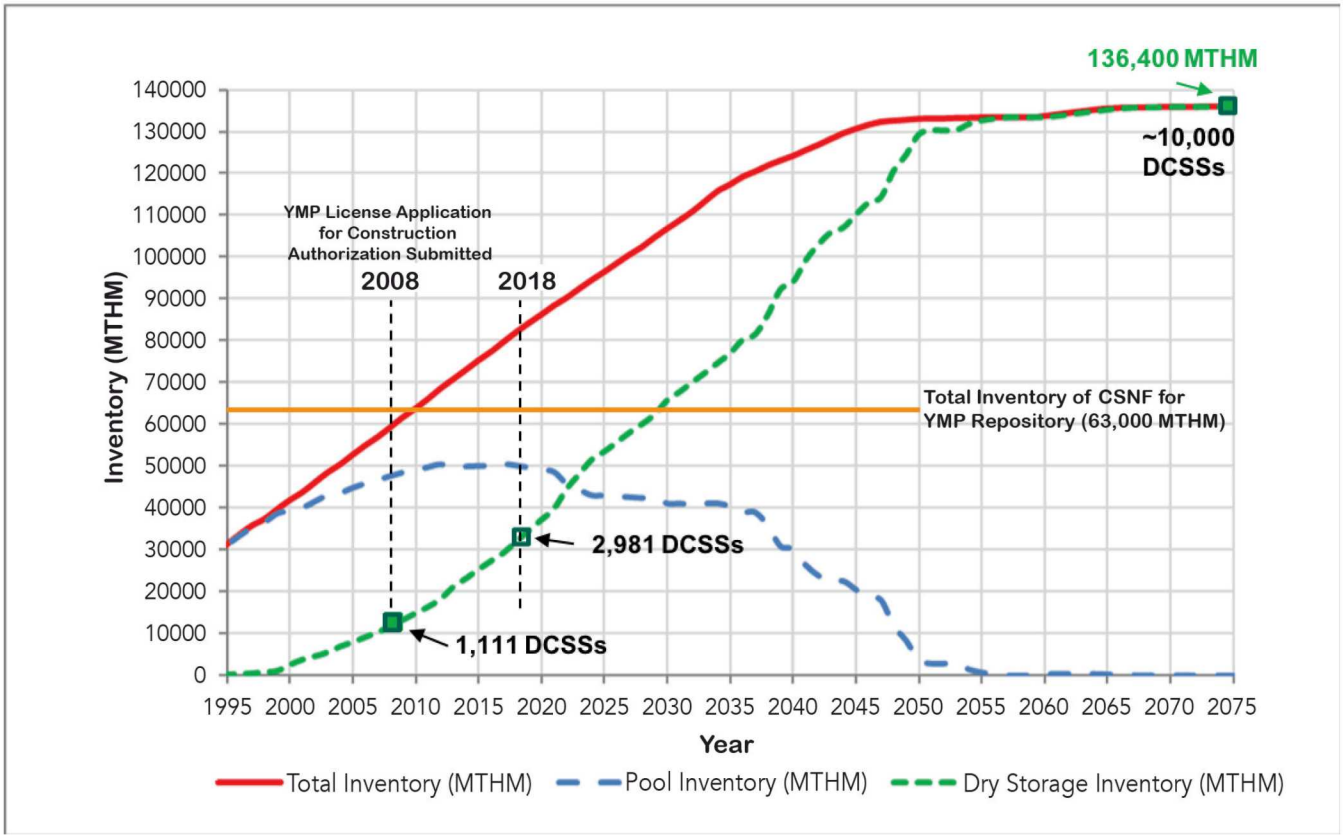


Map of the US commercial SNF storage from Bonano et al. 2018





US Projections of Commercial SNF Inventory



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

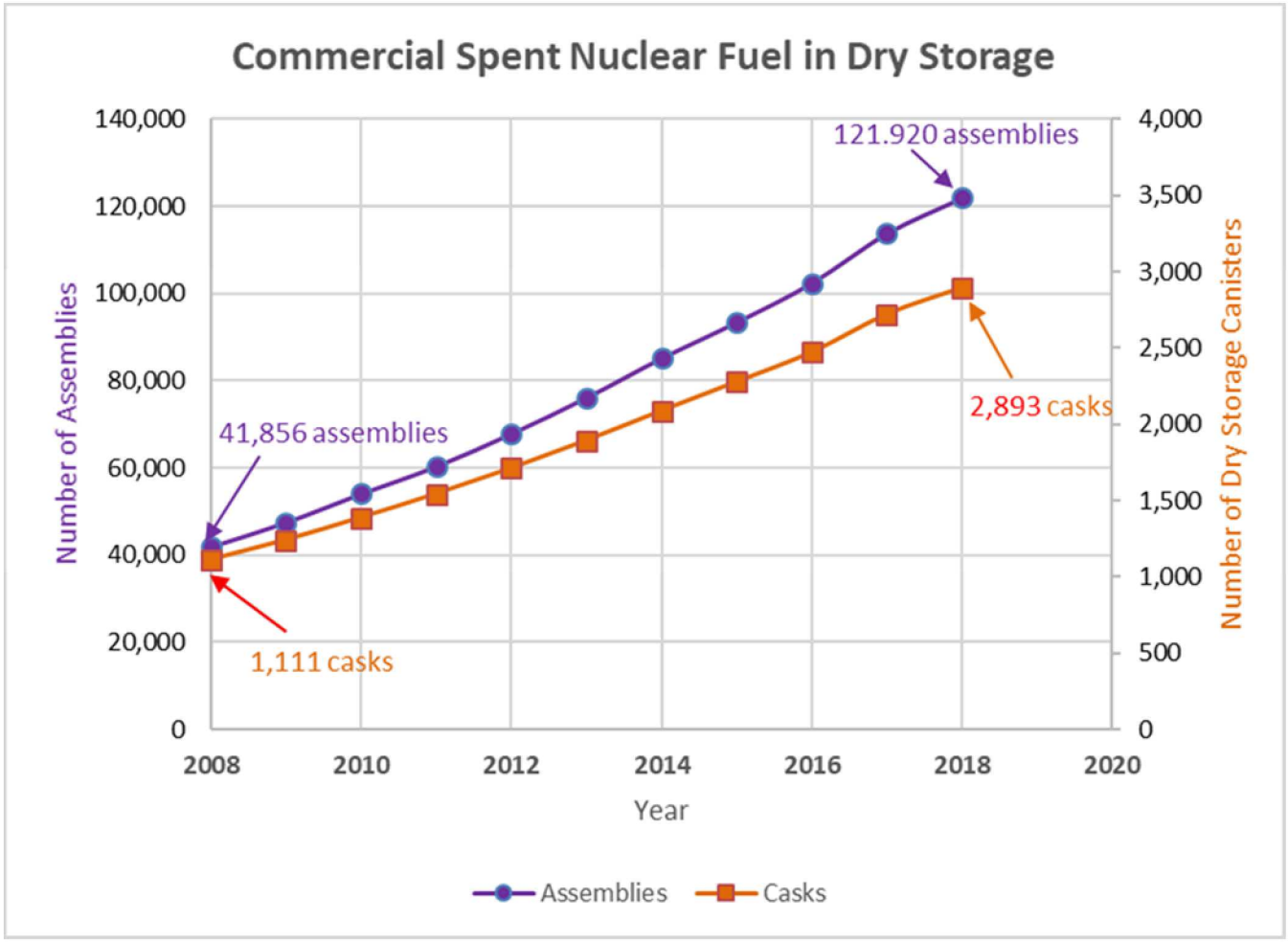
Approx. 80,000 MTHM (metric tons heavy metal) of commercial SNF in storage in the US as of Dec. 2017

Approx. 30,000 MTHM in dry storage at reactor sites, in approximately 2,900 cask/canister systems

- Balance in pools, mainly at reactors

Approx. 2200 MTHM of SNF generated nationwide each year

SNF Inventory in Dry Storage



- Approximately 160 new dry storage canisters are loaded each year in the US
- By mid-century ~10,000 DPCs are expected to be in service.

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

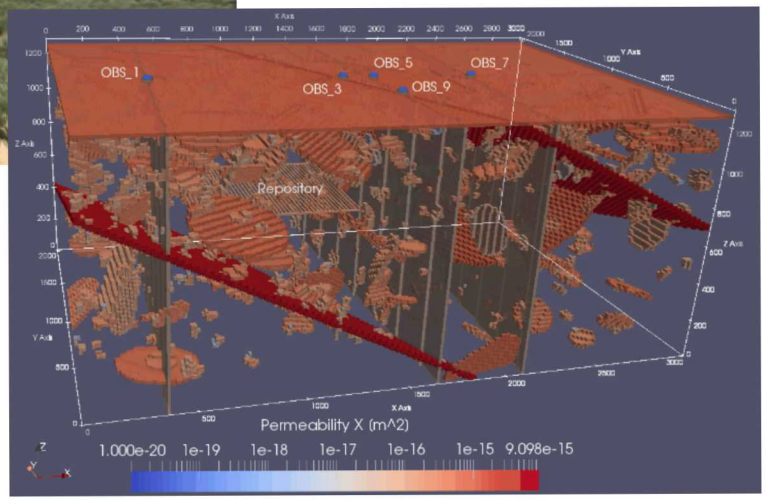
3) Storing spent fuel at surface facilities indefinitely, repackaging as needed

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

U.S. DOE Office of Nuclear Energy Spent Fuel & Waste Science & Technology (SFWST) R&D Campaign

Storage

Transportation



Disposal

SFWST R&D – Key Participants

- Managed by the US DOE NE Office of Spent Fuel and Waste Science and Technology (SFWST)
- Formerly referred to as the "Used Fuel Disposition" Campaign
- Nine national laboratories support the campaign

Argonne NATIONAL LABORATORY

BERKELEY LAB

INL Idaho National Laboratory

Science in the National Interest
Lawrence Livermore National Laboratory

Los Alamos NATIONAL LABORATORY

ornl OAK RIDGE NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

Sandia National Laboratories

SRNL SAVANNAH RIVER NATIONAL LABORATORY

SFWST Strategic Focus: Storage and Transportation R&D

Prepare for extended storage and eventual large-scale transport of spent nuclear fuel and high-level waste

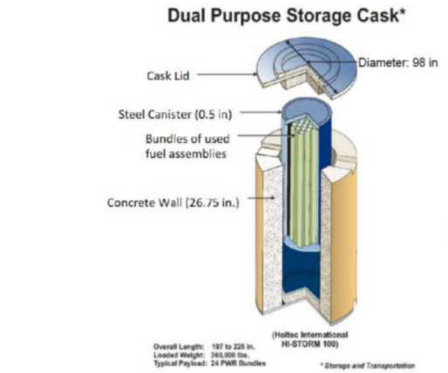
- Support the technical basis for evaluating:
  - Extended storage of spent nuclear fuel
  - Fuel retrievability and transportation after extended storage
  - Transportation of high-burnup spent nuclear fuel

Major Activities - Storage and Transportation R&D

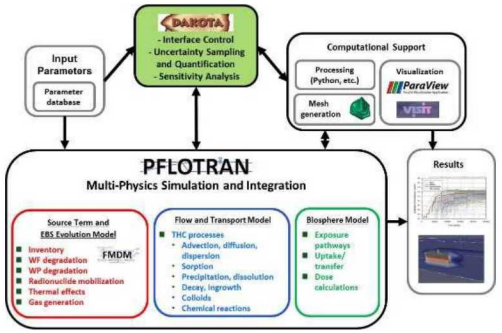
- High burnup fuel testing to support storage demonstration project
  - Non-destructive testing is complete
  - ORNL and PNNL are starting destructive testing
  - ANL has received samples and will test soon
- Corrosion
  - Improved understanding of salt deposition and decomposition rates, incubation times, pitting progression, and crack initiation and growth rates
  - Crack consequence experimental work and modeling has begun
  - Initiated repair and mitigation studies
- Transportation Handling Tests
  - Completion of 30 cm drop test; analyses of stress on fuel in progress
  - Designing a 9 m drop to get data on viability of pinch loads
- Residual Water After Drying
  - Analyzed gas samples from storage demonstration test and working to get more gas samples
  - Planning for experimental set up
  - Initiated consequence analysis
- Thermal Work
  - Vertical BWR experiments complete and horizontal test set up has begun
  - Blind round-robin modeling will continue

Major Activities - Disposal R&D

- Argillite, Crystalline, and Salt Research
  - Experimental data and modeling of bentonite performance at elevated temperatures
  - Improved techniques for modeling fracture flow and transport
  - Borehole heater test in progress at WIPP
- Options for Dual Purpose Canisters
  - Continue analysis of potential for post closure criticality
    - Conduct post closure criticality consequence analysis
    - Analyses of DPC fillers for criticality control
    - Modeling of DPC post closure performance including fillers
    - Design enhancement options for existing and future DPCs
  - Geotechnical considerations for post closure performance
- Geological Disposal Safety Assessment (GDSA)
  - High performance computing of system performance (PFLOTRAN)
  - Uncertainty Quantification and Sensitivity Analysis tools
  - Performance assessment inventory of DOE-managed wastes
- Enhanced R&D and International Collaborations to support concepts in multiple geologic media



Example of a dual-purpose canister inside a storage overpack (cask) (modified from Easton 2011).



SFWST: International Portfolio with URL Focus

Multinational Initiatives

Mont Terri Project
- Participate in experiments at Mont Terri clay URL in Switzerland

DECOVALEX Project
- Participate in model comparison initiative for several URLs related tasks in different host rocks

Colloid Formation & Migration Project
- Participate in colloid research at Grimsel granite URL in Switzerland (SFWST participation ended in 2015)

FEBEX DP
- Participate in FEBEX dismantling project, which evaluates bentonite-rock behavior after 18 years of heating

SKB Task Forces
- Participate in crystalline rock research centered around Äspö HRL in Sweden

HotBENT (starting soon)
- Conduct a high-temperature heater test to evaluate feasibility of 200°C waste disposal

Bilateral Research Collaborations

US-Republic of Korea (ROK)
- Participate in KAERI Underground Research Tunnel (KURT) experiments in crystalline rock
- High Level Bilateral Commission (HLBC), information exchange in used fuel disposal

US-Germany Salt Collaboration
- Participate in testing and modeling studies for thermal-mechanical and hydrological behavior of domal and bedded salt

US-Sweden COSC Collaboration
- Participate in testing hydrogeological characterization methods

There are several other international collaboration activities not focused on URL access and participation, e.g., the Thermodynamic Database Project, or NEA's Clay, Salt and Crystalline Clubs.

Concluding Remarks

- Because there is not an operational deep geologic repository for SNF and HLW in the US at present, the SNF inventory is storage at NPPs continues to grow.
- The current practice of dry storage at the NPPs is not optimized for transportation or disposal, leaving the US with three options or combinations, thereof:
  - Repackage the fuel
  - Directly dispose of the SNF in the DPCs
  - Indefinite storage with potential repacking every 100 years otr so
- Current R&D efforts in the US are focused on
  - Extended storage and eventual large-scale transport of spent nuclear fuel and high-level waste
  - Geologic disposal in different geologic media, including international collaborations; direct disposal of DPCs; and development of advanced modeling and simulation capabilities.

Thank you!

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