

Used Nuclear Fuel Storage and Transport

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Used Fuel and Nuclear Material Disposition

ANS FCWMD Nuclear Fuel Cycle Webinar

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The lifetime of a nuclear fuel assembly includes <6 years of operation at a commercial power plant followed by many decades of storage

- A uranium fuel pellet (1/2 in. height and diameter) contains the energy equivalent of 1 ton of coal or 17,000 ft³ of natural gas.
Typical reactors hold 18 million pellets!!
- Powering a 1 GWe nuclear plant for a year can require disposal of 27.6 mt of radioactive materials
 - 90% (by volume) is low-level waste, 7% is greater than class C waste, and 3% is high-level waste
- Used nuclear fuel (UNF) is high level waste that is currently stored throughout the US at ~80 sites in 34 states, including 14 shutdown reactor sites
- UNF inventory increasing annually at ~2,000 MTHM/y

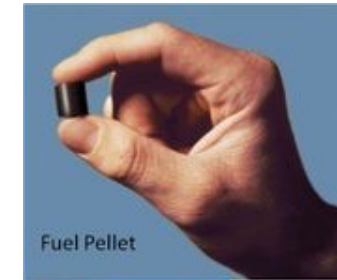
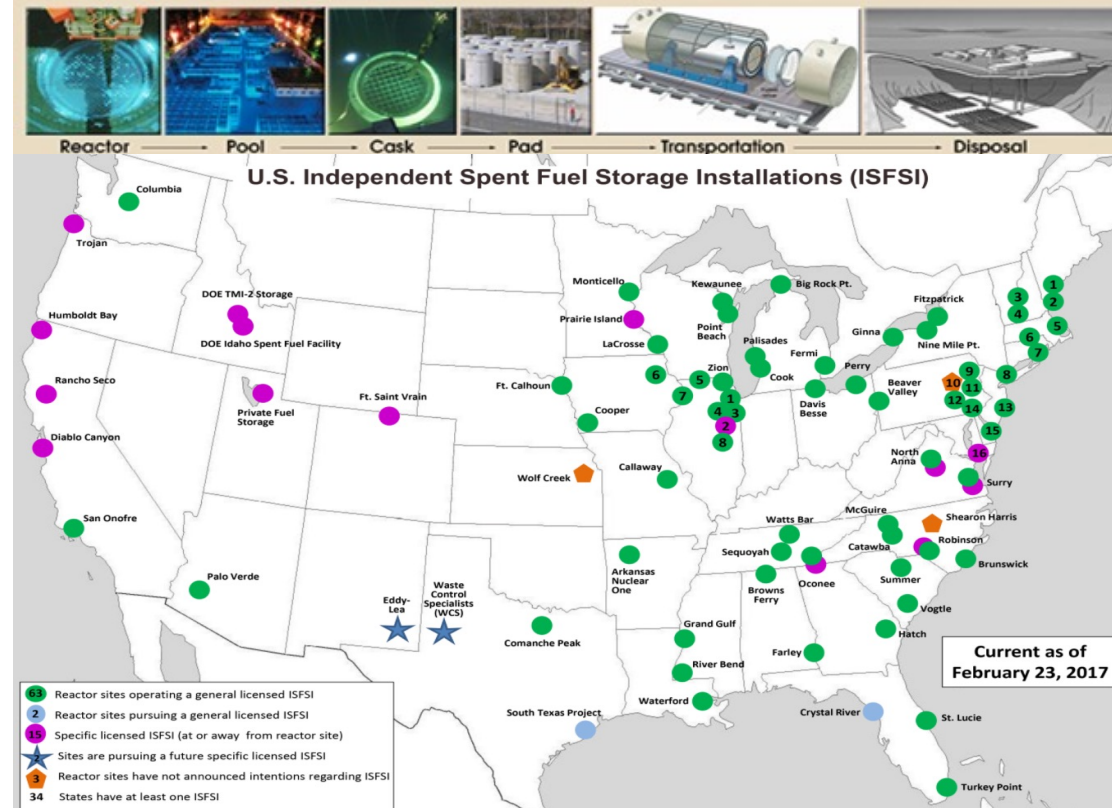


Image: Nuclear Energy Institute.

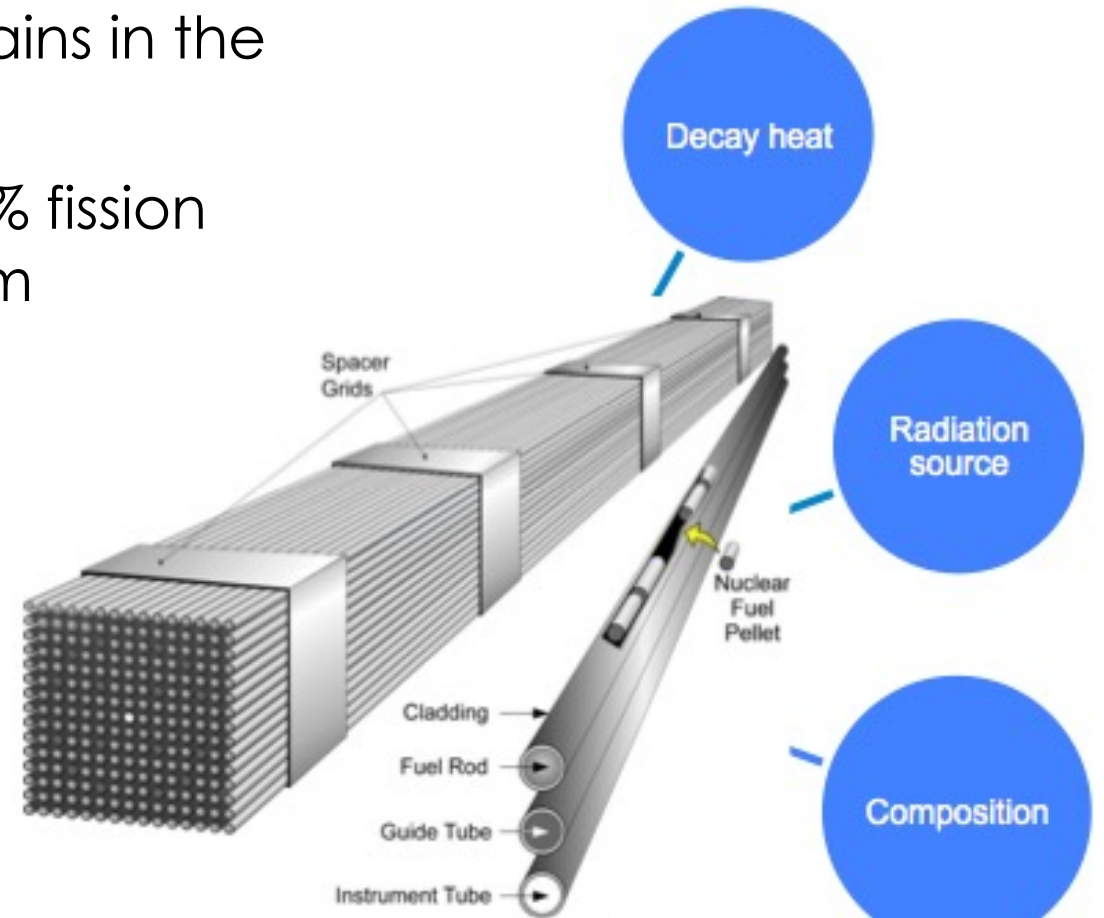
Fuel Pellet



Sources: <http://css.umich.edu/factsheets/nuclear-energy-factsheet>; <https://www.energy.gov/ne/articles/5-fast-facts-about-spent-nuclear-fuel>; <https://www.gao.gov/assets/gao-12-797.pdf>; <https://www.nrc.gov/images/reading-rm/doc-collections/maps/isfsi.png>

After reactor operation, UNF still contains harvestable energy

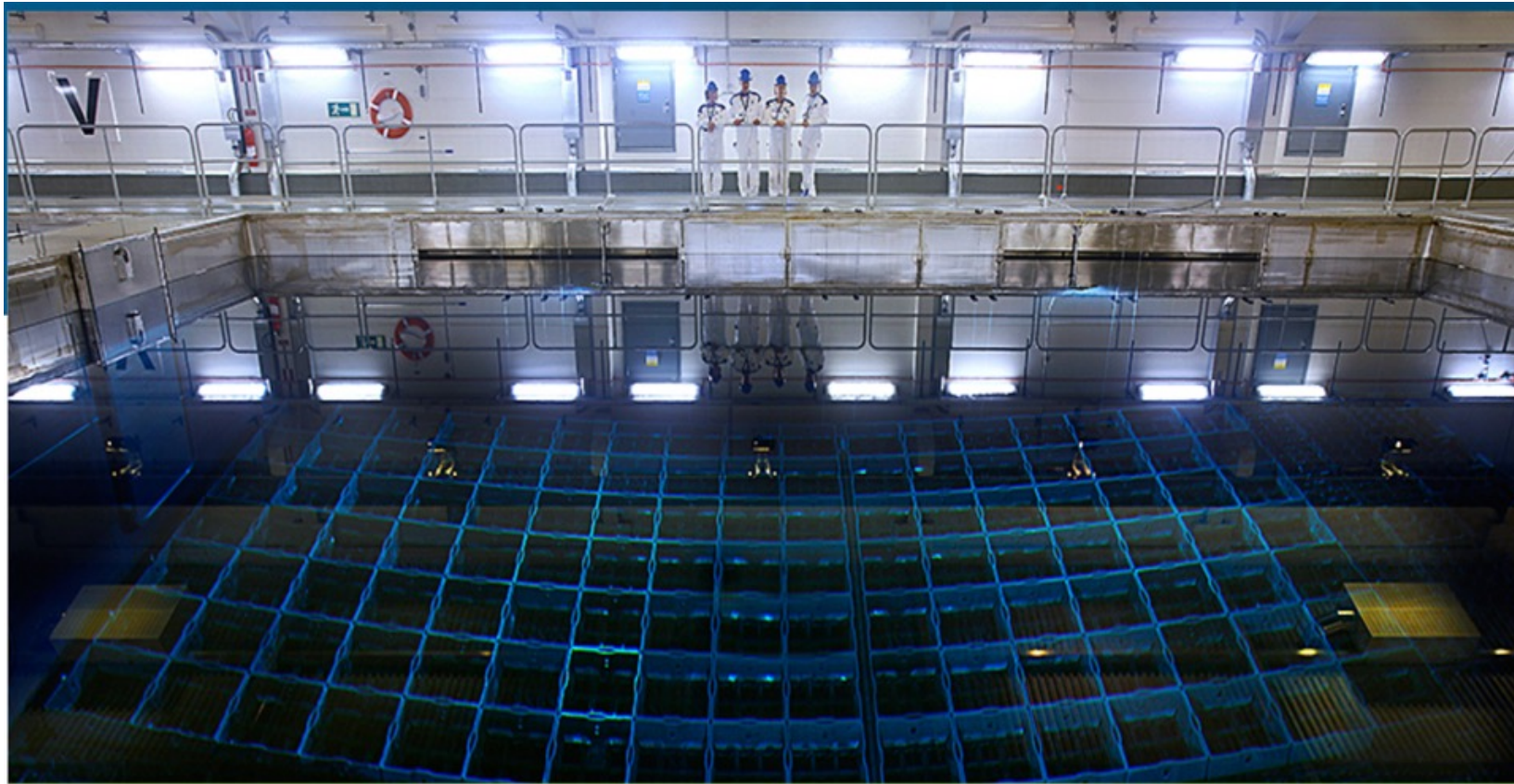
- More than 90% of its potential energy remains in the UNF, even after reactor operation
- Used fuel is roughly 95% non-fissile U-238, 3% fission products, 1% fissile U-235, and 1% plutonium
- Radiation source
 - Gamma rays, high energy photons
 - Neutrons, high energy particles
 - Alpha and beta – low energy particles that are contained within the fuel rods
- Thermal Heat
 - As much as 1.5 kW per fuel assembly



An LWR nuclear fuel assembly and its basic components. Image: J.C. Wagner, Used Nuclear Fuel Disposition, INL/JOU-16-38726, May 2016.

For a few years following reactor discharge, UNF is stored under water in the used fuel pool for cooling and radiation shielding

CLAB UNF pool storage facility in Sweden



Picture taken from: <http://www.skb.com/our-operations/clab/>

After pool storage, utilities may move UNF to dry storage facilities that provide passive cooling, shielding, and containment

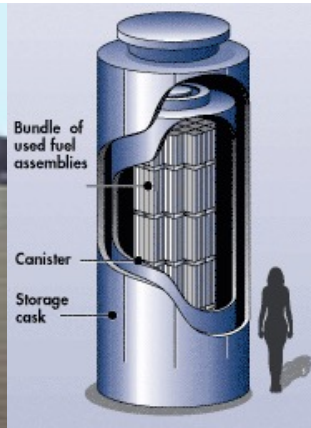


A dry storage canister

Photo: ORNL



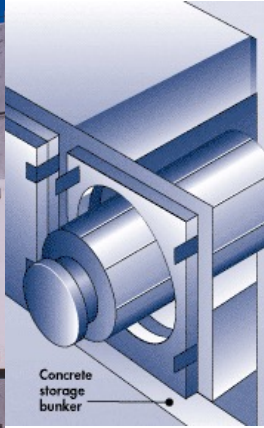
Vertical storage system



Picture taken from:
<https://holtecinternational.com/productsandservices/wasteandfuelmanagement/dry-cask-and-storage-transport/hi-storm/hi-storm-umax/>



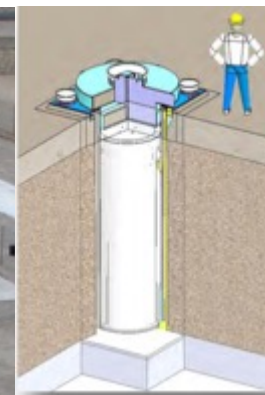
Horizontal storage system



Picture taken from:
<https://www.orano.group/usa/en/our-portfolio-expertise/used-fuel-management/used-fuel-storage/top-10-faqs>



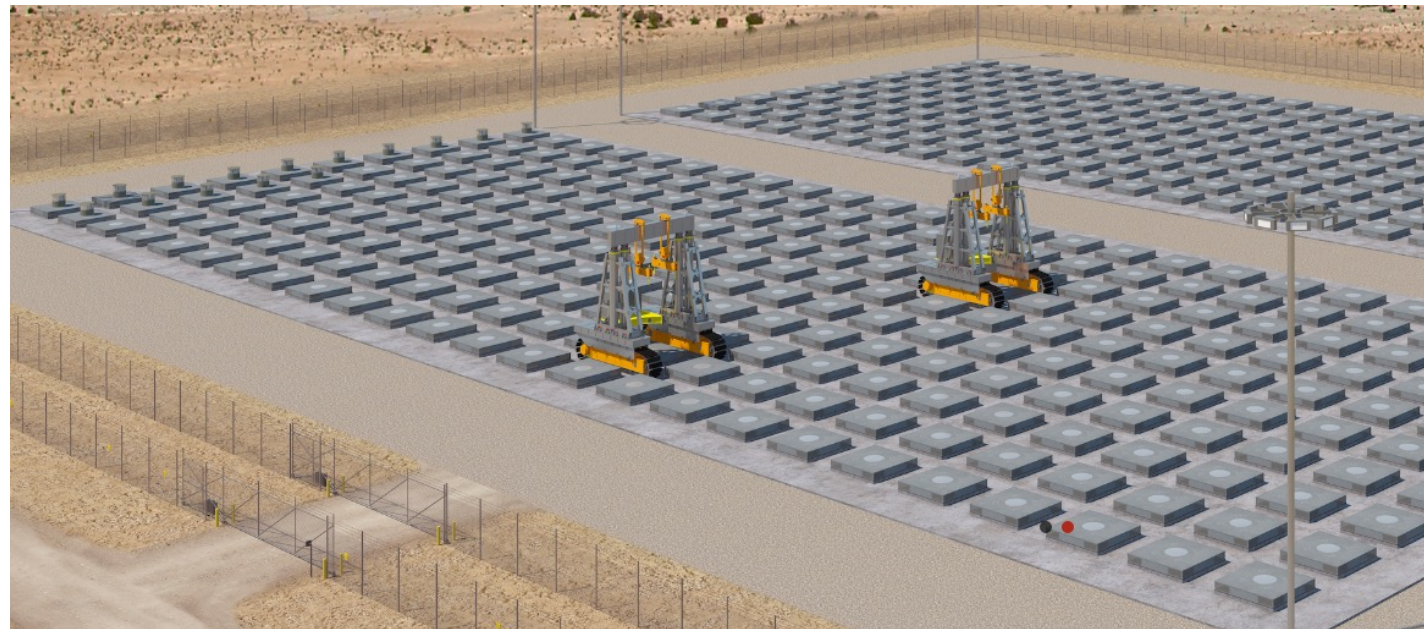
Underground "below grade" storage system



Picture taken from:
https://www.songscommunity.com/internal_redirect/cms.ipressroom.com.s3.amazonaws.com/339/files/20181/Holtec_Presentation_CEP_Special_Meeting_10-14-14.pdf

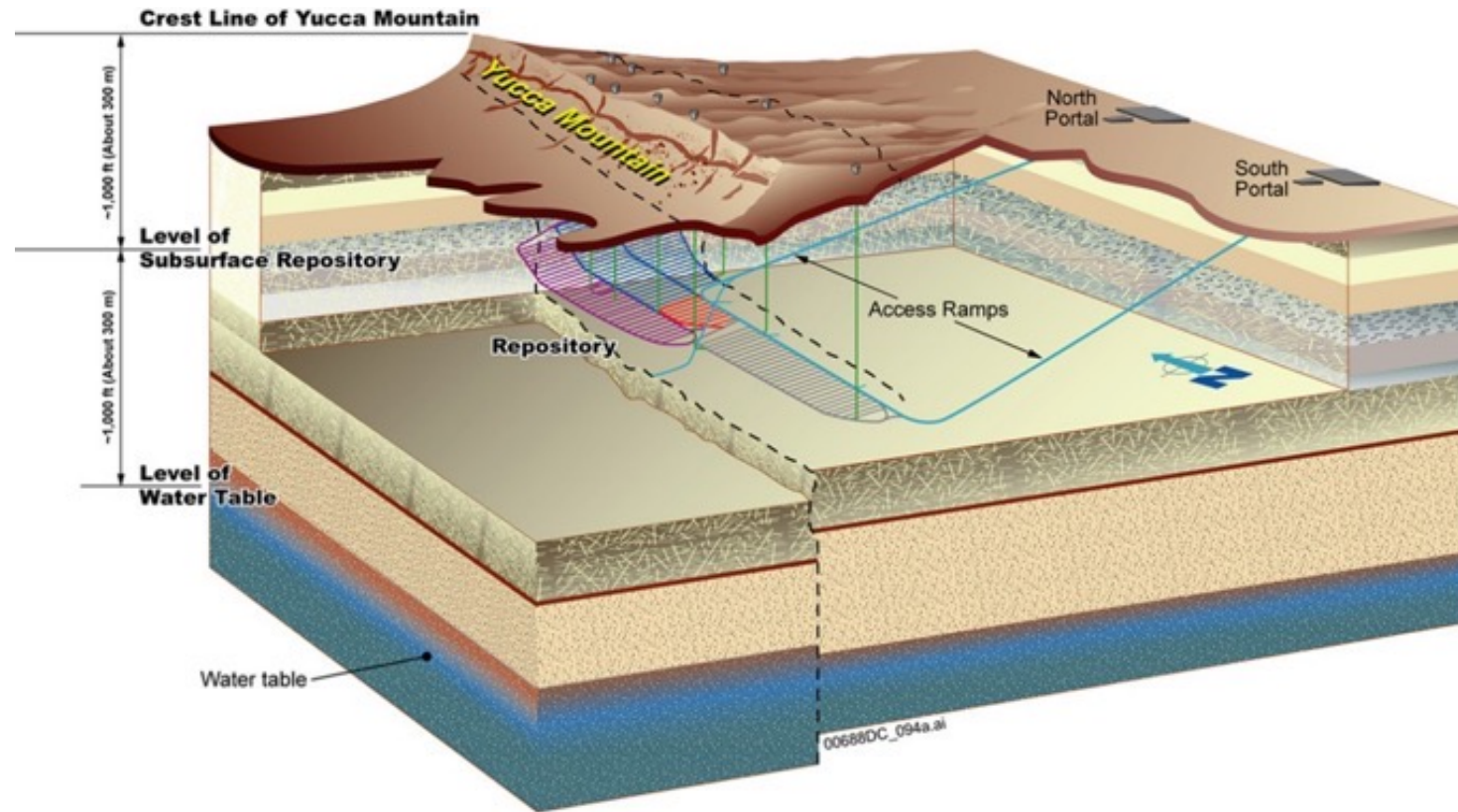
Consolidated (or Centralized) Interim Storage facilities are sites that can accept UNF from other sites for temporary storage

- Two sites – 1 in Texas and 1 in New Mexico - have applied to NRC for an interim storage license
- These sites are not meant as a permanent repository
- Provide the near-term ability for shut down reactor sites to close their interim storage facility
- Opportunities to create efficiencies in the storage and disposal process



Conceptual image of an autonomous consolidation facility, Holtec International

Underground repositories for permanent disposal



- An ideal repository is remote and geologically stable
 - One example, Yucca Mountain in Nye County, NV

Getting the UNF from interim storage sites to a repository requires handling and transportation



- UNF transportation containers are designed to withstand severe credible transportation accidents and significantly limit radiation at the surface of the structure to low levels that meet regulatory requirements for safety.
- A dedicated train design, the ATLAS, is being developed by DOE-NE
 - Two locomotives
 - Buffer railcar
 - One or more Atlas railcar(s)
 - Buffer railcar
 - Rail Escort Vehicle



Image source:
https://www.energy.gov/sites/default/files/styles/full_article_width/public/2020/05/f74/SNF_blog.png?itok=lzw9IKf8

The Department of Energy – Nuclear Energy is investigating the performance of UNF during transport

- The high burnup spent fuel data project investigates the characteristics of the fuel during and after interim storage, and under transport conditions
 1. Thermal profiles and extended effects
 2. Stress profiles of the fuel rod
 3. Cladding hydride effects
 4. Completeness of canister drying during loading
 5. Corrosion of the storage canister
 6. Consequences of canister failure
 7. Fuel transfer and repackaging options
- The multi-modal transportation test collected data on loads applied to the fuel during transport
 1. Heavy-haul truck from within Spain ~ June 14, 2017
 2. Coastal sea shipment from Santander to large northern European port ~ June 27, 2017
 3. Ocean transport from Europe to Baltimore
 4. Commercial rail shipment from Baltimore to Pueblo, Colorado ~ Aug 3, 2017
 5. Testing completed at the Transportation Technology Center, Inc.
 6. Return trip to ENSA, September 5, 2017

