Spent Nuclear Fuel, Low Level Radioactive Waste and Decommissioning

Vermont Legislature
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Topics

- Spent Nuclear Fuel
- Low Level Radioactive Waste
- Decommissioning

Understanding key technical and policy issues will foster the best legislative decisions

Spent Nuclear Fuel ("SNF")

- Isotopes
- What is nuclear fuel?
- How does nuclear fuel become "spent"
- Main Characteristics of SNF
- Storing and disposing of SNF
- US Commercial SNF history and policy
- Dry storage
- SNF Storage Capacity at the Vermont Yankee
- Vermont Yankee Dry Storage Technology and Site
- Vermont SNF Considerations

Isotopes

- Chemical reactions between elements are determined by electrons
- Nuclear reactions involve protons and neutrons in the nucleus
- Neutrons help keep the nucleus “stuck together”
- Examples

Element	Isotope	Protons	Neutrons	Total	Half life	Decay Particle
Helium	He-4	2	2	4	Infinite / stable	
Carbon	C-12	6	6	12	Infinite / stable	
Carbon	C-14	6	8	14	5,600 years	electron
Nitrogen	N-14	7	7	14	Infinite / stable	
Nitrogen	N-15	7	8	15	7.4 seconds	electron
Cobalt	Co-59	27	32	59	Infinite / stable	
Cobalt	Co-60	27	33	60	5.3 years	electron
Uranium	U-235	92	143	235	700,000,000	He++
Uranium	U-238	92	146	238	4,500,000,000	He++
Uranium	U-239	92	147	239	23.5 minutes	electron
Plutonium	Pu-239	94	145	239	24,000 years	He++

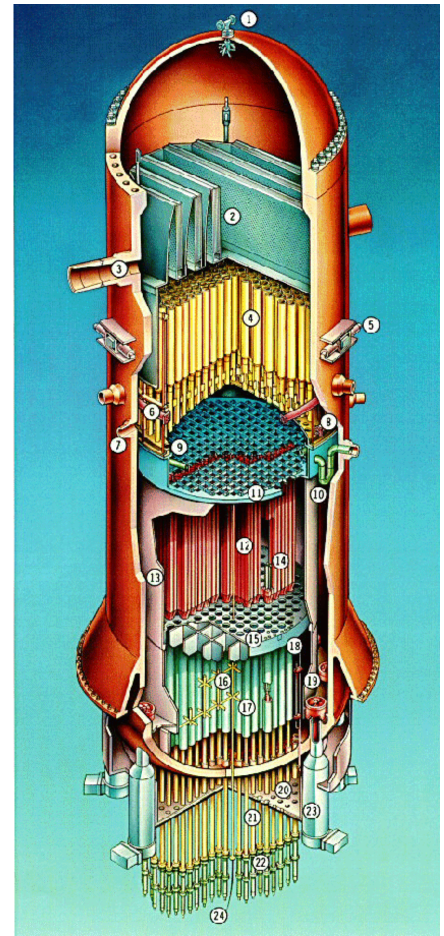
Isotopes Continued

- Radioactivity: energy from the nucleus in the form of particles and rays
  - Gamma rays (like powerful X-rays) require thick shielding
  - Electrons (beta particles) are stopped by a thin layer of metal
  - Helium atoms (alpha particles) are stopped by a sheet of paper
- All unstable isotopes decay over time into stable isotopes
- The half life and decay particle tell us a lot about the degree of radiation hazard
- General characteristics of unstable or radioactive isotopes

Half life	Decay rate	Decay Particle	Intensity of Radiation
Short	Fast	Electron	High
Long	Slow	He++	Low

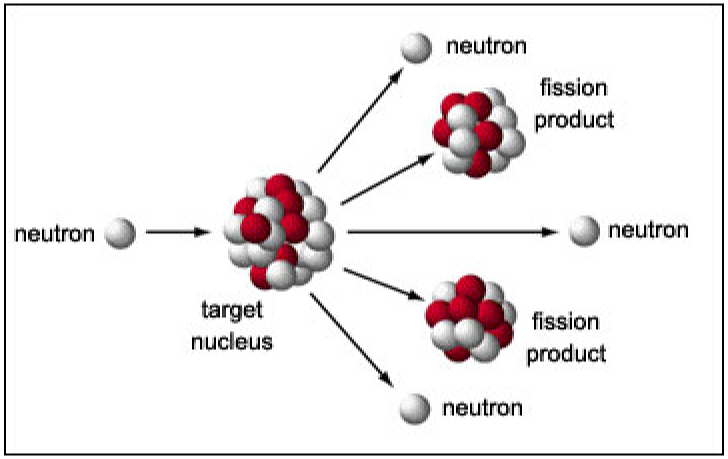
What is Nuclear Fuel?

- Uranium Oxide (UO_2) in solid ceramic pellets
- The Uranium has been enriched in the U-235 isotope
- The pellets are in hollow steel rods or “pins”
- Pins are grouped into bundles or assemblies
- Reactors are designed for a specific number of assemblies, e.g. the Vermont Yankee reactor is designed for 368 bundles



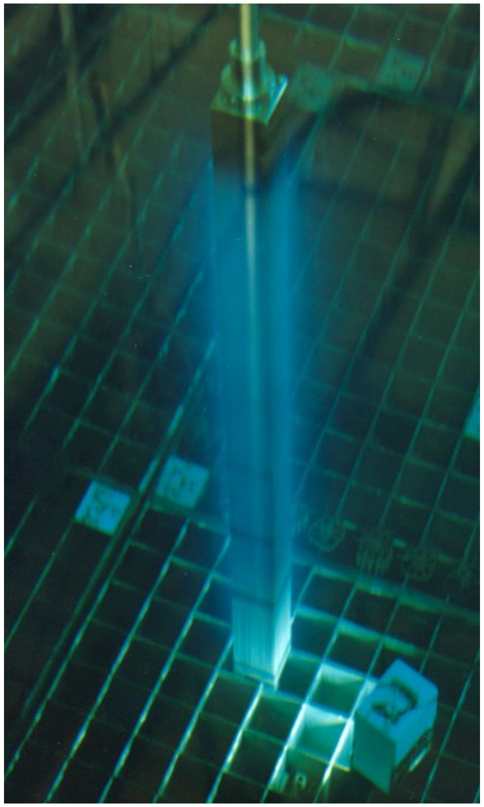
How does nuclear fuel become “spent”?

- U-235 and Pu-239 fission of “split”, producing heat, fission products and 2-3 neutrons
- U-238 is converted into Pu-239 and other “heavy” isotopes
- Neutrons are the key to both the fission and conversion processes
- Depletion of U-235 and accumulation of fission products dampens the fission process



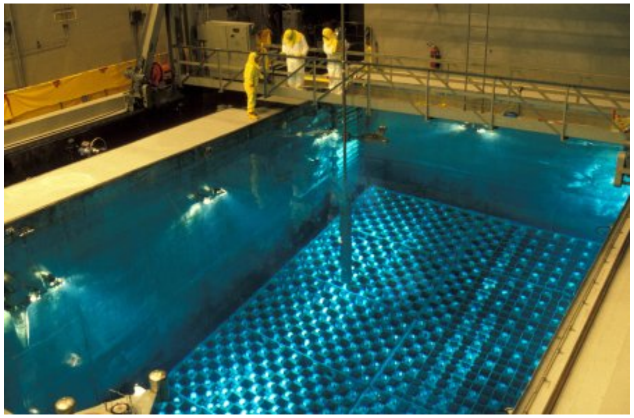
Main Characteristics of SNF

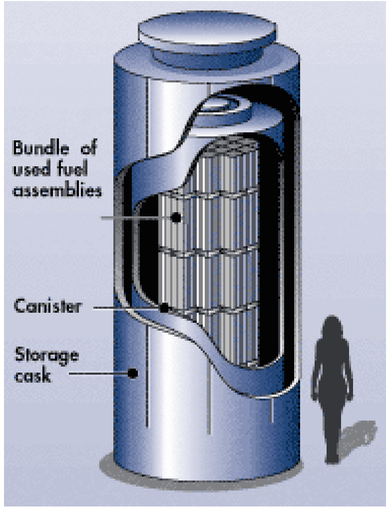
- Still in solid form, but internal composition has changed
  - U-235 depleted
  - U-238 about 10% converted
  - Pu-239 being produced and fissioned
  - Other “heavy” isotopes
  - Fission products
- Fission products are the primary source of the radiation exposure hazard and residual heat production after SNF is taken out of the reactor
- Fission product half lives range from milliseconds to around 30 years
- There are over 750 fission product isotopes that over time decay into approximately 34 elements



Storing and Disposing of SNF

- Short term it needs shielding and cooling in the spent fuel pool
- After five years the residual heat production and radiation levels are low enough to allow it to move to dry storage
- Longer term is a question of national policy





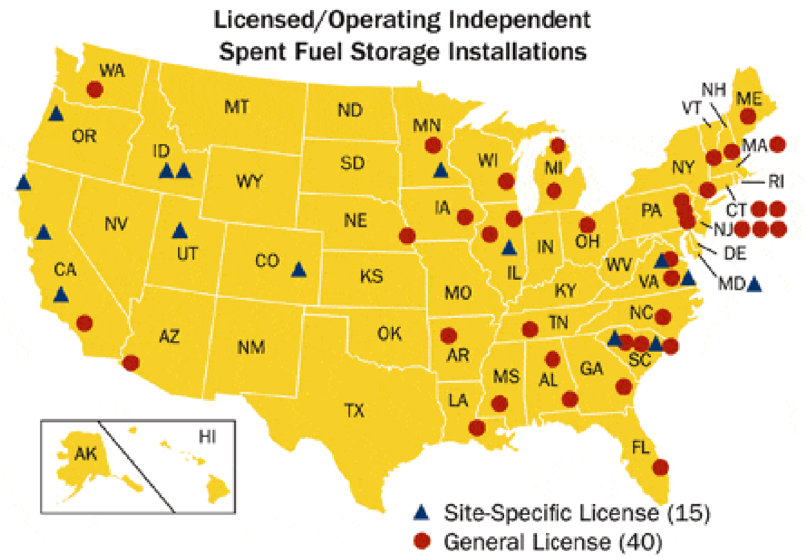
US Commercial SNF History and Policy

- 1960's – 1970's
  - Anticipation of recycling (reprocessing) and geologic disposal of residues
  - Uranium was a government monopoly, considered scarce and expensive
  - Subsequent opening of the Uranium market showed it to be plentiful and cheap
- 1979 Carter executive order against commercial reprocessing
- 1982 Nuclear Waste Policy Act ("NWPA")
  - Regional interim storage
  - Permanent repositories
  - Standard contracts with utilities for SNF disposal, 1998 date
  - Established Nuclear Waste Fund, $0.001/kwh payments
- 1987 NWPA Amended
  - Response to DOE progress on site selection
  - Federal effort on regional interim storage prohibited until a repository licensed
  - Yucca Mountain, NV, selected by Congress
  - If Yucca Mountain unsatisfactory, report back to Congress
- 1990's advent of dry storage
- 2002 Yucca Mountain satisfactory
- 2008 Yucca Mountain license application submitted to and accepted by US NRC

Dry storage is the default long term interim US policy

Dry Storage

- 55 Independent Spent Fuel Storage Installations (ISFSI) in 33 States
- All aspects of dry storage are regulated by the US NRC
- Two types of site licenses
  - Site specific (15)
  - General (40), including Vermont Yankee
- Primary siting criteria involve:
  - Soil Stability
  - Seismic
  - Air temperature
  - Flooding
- Canister and cask systems, including transportation, are certified by the US NRC
- Security is required for ISFSI's until the last SNF leaves the site



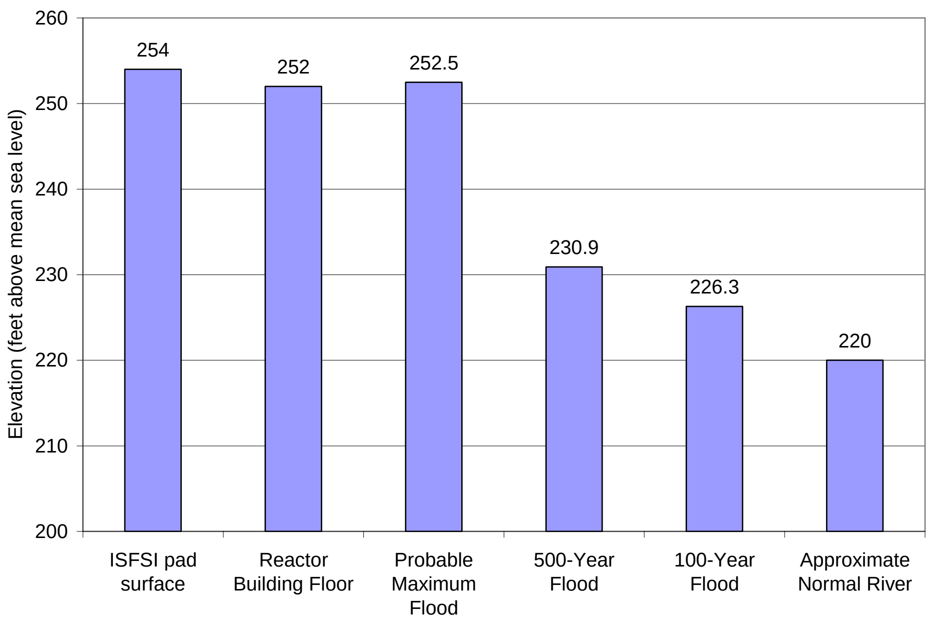
SNF Storage Capacity at Vermont Yankee

- All SNF produced at Vermont since startup in 1972 is stored at the site
  - Until recently, all in in the spent fuel pool
  - Dry storage added due to limits of spent fuel pool
- Current inventory
  - 2819 (see note) bundles in the spent fuel pool
  - 340 bundles in 5 dry storage canisters (68/canister)
- The existing ISFSI pad, which can accommodate up to 36 canisters, in combination with the spent fuel pool, can meet storage needs through 2032
- Additional dry storage capacity will be needed to empty the spent fuel pool as part of decommissioning

Note: Corrected from 1911 number used in January 29, 2009 legislative presentation

The Vermont Yankee Dry Storage Technology and Site

- Vermont Yankee uses
  - A general license
  - The Hi-Storm 100 System
- The Hi-Storm system meets all Vermont Yankee site criteria
- The Hi-Storm system is certified for submergence up to 125 feet, however it is reasonable to assume that the ISFSI will never be flooded
- Preliminary independent geological evaluation of the site indicates it to be stable with no indication of flood hazard beyond that already evaluated
- Site elevation and flood data from independent surveys, FEMA and reports to NRC

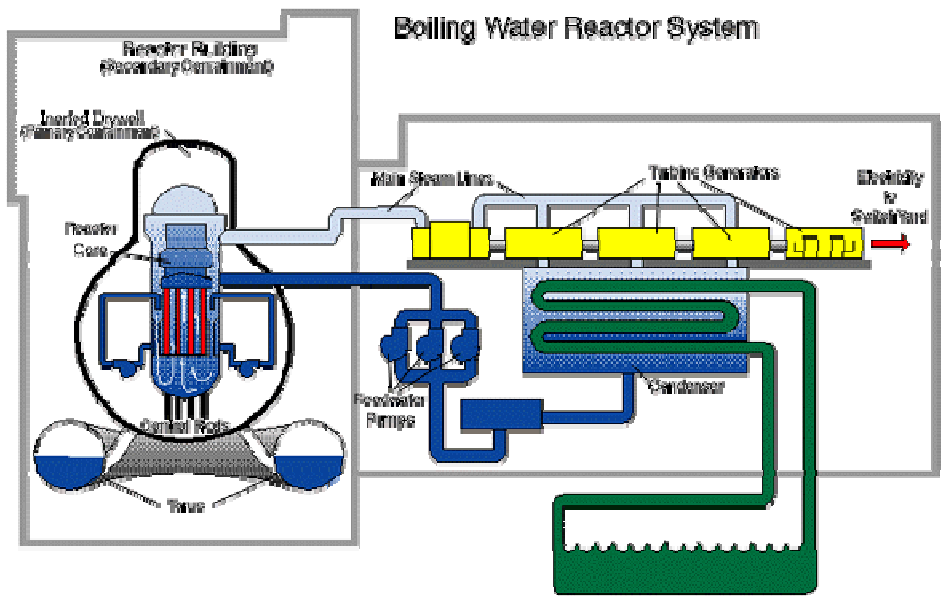


Vermont SNF Considerations

- The Vermont Yankee Dry Storage meets NRC requirements and should not be regarded as posing an imminent threat to public health and safety. The existing ISFSI pad provide in-place storage capability for fuel produced during the license renewal period.
- The key date for SNF storage at Vermont Yankee is when the last bundle leaves the site
- Success at the national level provides the only substantive resolution of long term interim storage at the site
- Given the history of Congress and Administrations over the past, it is reasonable to contemplate that SNF at Vermont Yankee, and other commercial nuclear plants in the US, will be at the reactor sites well past the end of plant operation and possibly after decommissioning of the power plant

Low Level Radioactive Waste ("LLW")

- What is it?
  - Class A: contaminated clothes, equipment, and some plant water resins
  - Class B: concentrated water purification resins
  - Class C: materials directly exposed to neutrons in the reactor core
- What do you do with it?
  - Reduce volume by compaction, incineration and metal melting
  - Burial in NRC approved sites
- Burial site options
  - Class A, Envirocare in Utah
  - Class B & C, pending in Texas



US Low Level Radioactive Waste History and Policy

- Barnwell, SC and Hanford, WA have historically provided the bulk of US LLW disposal capability
- In response to concerns, Congress passed the Low Level Radioactive Waste Policy Act in 1980
  - Objective was to motivate the development of additional disposal sites
  - States were encouraged to join into "Compacts" where they would agree on development of a site within the compact
  - Non-compact states could be excluded from burial sites
- A new site was developed and opened in Clive, Utah, accepting Class A LLW from all states
- Most "Compacts" have not been successful in agreeing on development of new sites
- Closure of Barnwell and Hanford to non-compact members has eliminated Class B and C disposal options
- Texas, Vermont's Compact partner, is making good progress on opening a facility that will accept Class B and C waste
- Economics has and will continue to play an important role in availability of and access to LLW waste disposal

Vermont LLW Considerations

- LLW disposal during plant operation is a relatively low profile activity that can weather some changes and disruptions in national or state policy
- Class A, B and C disposal capability is essential for decommissioning of Vermont Yankee
- The cost and availability of LLW burial is the major variable in the cost of decommissioning Vermont Yankee
- History suggests that access to disposal sites and cost of disposal can and does change over time and should not be taken for granted.

Decommissioning

- Decommissioning Options
- Experience To-date
- Key Decommissioning Requirements
- Vermont Yankee Decommissioning Cost Estimates
- Vermont Yankee Decommissioning Funding
- Vermont Decommissioning Considerations

Decommissioning Options

- DECON – equipment, structures and portions of a facility and site containing radioactive contaminates are removed or decontaminated to allow for unrestricted use shortly after cessation of operations
- SAFSTOR – essentially deferred DECON, decommissioning must be complete within 60 years, assumptions about the SAFSTOR period are commonly timed to correlated with assumptions about removal of SNF
- ENTOMB – radioactive contaminates are encased in a long live material and the entombed structure is monitored and maintained until the radioactive material decays to a level permitting unrestricted release of the property

Decommissioning focuses on removal of radioactive contamination.

SNF storage and site restoration, while important, are separate issues.

Experience To-date

- DECON complete, 11 sites
  - Pathfinder, Elk River, Saxton, Shippingport, Shoreham, Fort St. Vrain, Yankee Rowe, Trojan, Haddam Neck, Maine Yankee, Big Rock Point
- DECON in progress, 2 sites
  - Rancho Seco, San Onofre 1

License renewal is pushing most decommissioning thinking farther into the future

- SAFSTOR, 11 sites
  - GE VBWR, CVTR, Fermi 1, Indian Point 1, Peach Bottom 1, Humbolt Bay 3, Dresden 1, LaCrosse, Zion 1&2, Millstone 1
- ENTOMB
  - Hallam, Pique, Bonus

Key Decommissioning Requirements:

- Removal of the SNF from the spent fuel pool
- LLW burial access for Class A, B and C waste
- Money to cover the costs

Vermont Yankee Decommissioning Cost Estimates (January 2007 TLG Study, Millions of $2006)

DECON Option

	Low	High
License Termination	469	469
Spent Fuel Management	142	384
Site Restoration	44	40
Total	655	893

SAFSTOR Option

	Low	High
License Termination	455	450
Spent Fuel Management	221	501
Site Restoration	41	40
Total	717	991

Vermont Yankee Decommissioning Funding

- The Vermont Yankee Decommissioning Trust Fund has declined due to turmoil in the financial markets, other companies are having similar experiences

- There is no indication yet as to how NRC will address declines in Fund balances due to recent declines in the financial markets

- NRC will require that the Fund be first applied to completing License Termination

	Balance
September 30, 2007	$440 M
June 30, 2008	$414 M
December 31, 2008	$ 372 M

Note: the December 32, 2008 fund balance of $372 M, provided by Entergy on January 29, 2009, will be independently verified

Vermont Decommissioning Considerations

- The January 2007 TLG study is the best available, but the precision of the numbers can lead users to a false sense of confidence. The underlying assumptions can vary significantly between now and when decommissioning takes place.
- Vermont is well position with LLW burial options given the progress of Texas in developing a new site. This option needs to be managed with an understanding that decommissioning could be many decades in the future
- Removal of SNF is dependent upon national policy success which is arguably very uncertain, the cost of SNF management is consequently similarly uncertain
- Given the uncertainties in final costs and that they may be far in the future with new evolutions in ownership compared to when Vermont Yankee is producing power, Vermont should consider strategies that motivate all parties (the state, customers and the plant owner) to support adequate fund collection. Erring on the side of what seems like over collection today could be of great benefit in the future
- While premature shutdown and owner bankruptcy at some point in the future are not anticipated outcomes, they are possible and should be examined, including how Vermont involvement in the economic aspects of Vermont Yankee could be interpreted as assumption of a decommissioning obligation by the state of Vermont