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# **Criticality Evaluation of Transporting and Direct Disposal of Electrorefiner Salt Waste**

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**INL-Sandia Interchange on Direct Disposal of Electro-Refinery Waste**  
**Albuquerque, NM**  
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# **Talk discusses three aspects of criticality evaluation for electrorefiner salt waste**

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- **Transporting ER waste to a salt repository in casks that current are licensed to transport RH-TRU waste to WIPP**
- **Direct disposal of ER waste in mined repository in salt**
- **Direct disposal of ER waste in deep borehole repository in granite**

# Shipping ER waste feasible in existing casks if fissile content of ER canisters adjusted



Cask	Containers	Fissile Mass (FGE/contain)	Activity (PE-Ci/contain)	Content Weight (kg/contain)	Shipment Configuration on Truck	Number of Shipments
RH-TRU-72B	1 canister	<315	1800	5250 lb	1 cask	217
10-160B	10 55-gal drums	<200/drum	1800/drum	1000 lb/drum	1 10 pack	34
TRUPACT-II (or ½ in HALFPACT)	Two 7-pack of 55-gal pipe overpack (POC)	<175/POC (or <650/pack?)			2 TRUPACTs 1 HALFPACT	12 (or 21)
	Two 3-pack of lead-lined 55 gal drum Criticality control container (CCC)	<380/CCC		160 kg/drum	3 TRUPACTs	12

# Studying possibility of amending NRC Certificate of Compliance for existing casks



Study in FY15 is

- Examining the feasibility of increasing the fissile gram equivalent (FGE) limits on existing casks to reduce the number of waste shipments
- Examining the feasibility of these increased FGE loads meeting the radiation dose limits at the surface of the cask

# Current progress on transportation evaluation

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- Selected RH-TRU 72-B to model first since cask geometry available
- Criticality will be modeled in KENO,
- Radiation shielding will be modeled in MONACO

# Some calculations done with conservatively bounding fuel

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- **Fuel isotopic inventory, highest enrichment from fresh fuel**
  - **U-235: 1.25 wt%**
  - **U-236: 0.0392 wt%**
  - **U-238: 98.7108 wt%**
- **U wt% in each fuel replaced with the same wt% of this composition**
- **Am and Pu inventories unchanged**

# $k_{\text{effective}}$ values in RH-TRU 72-B cask with one transport container inside

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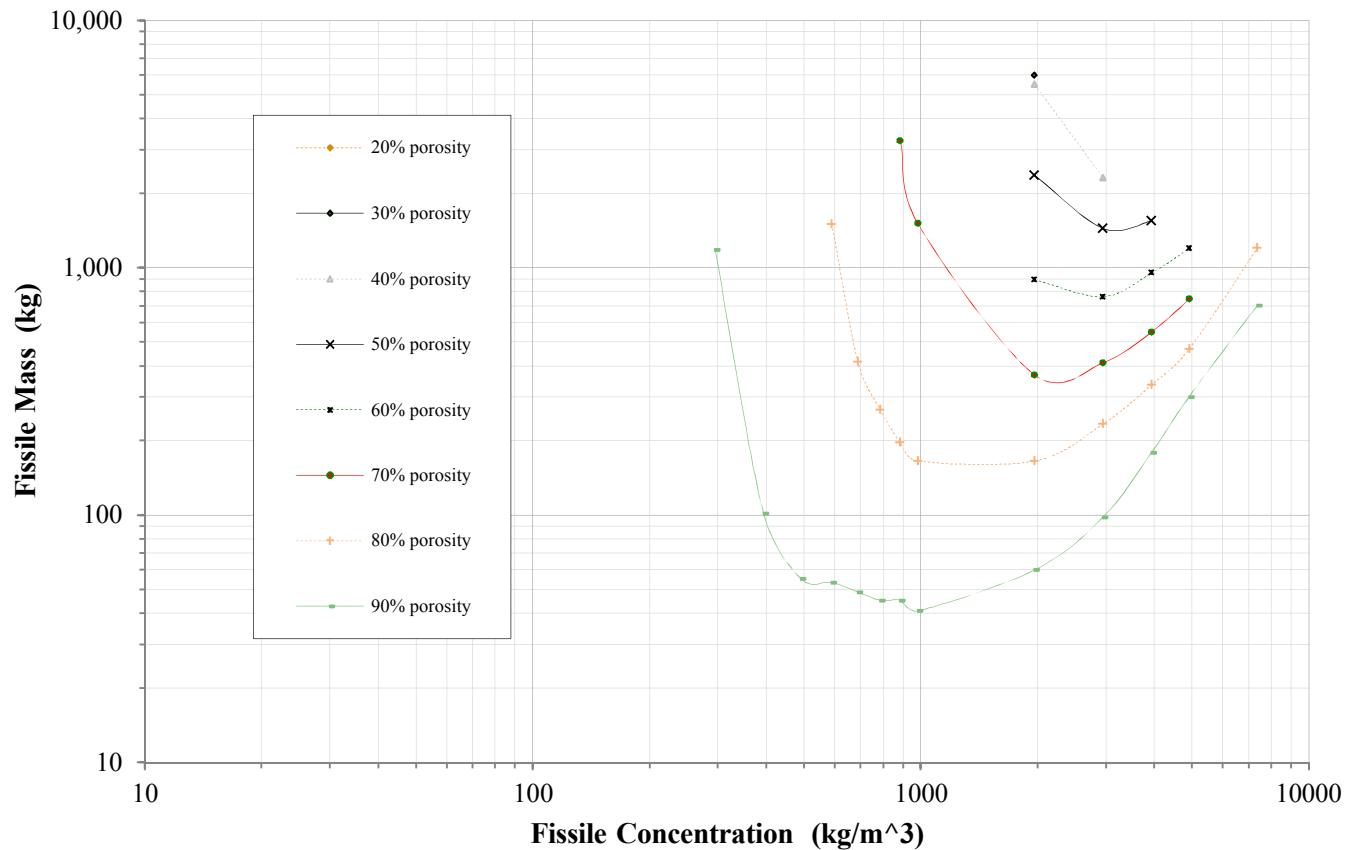


- Salt-IV fuel:
  - 0.02927 +- 0.00014
- Salt-V fuel:
  - 0.03956 +- 0.00017
- NRX-IV fuel:
  - 0.02345 +- 0.00011
- NRX-V fuel
  - 0.03956 +- 0.00017

# Last year looked at criticality in mined salt repository



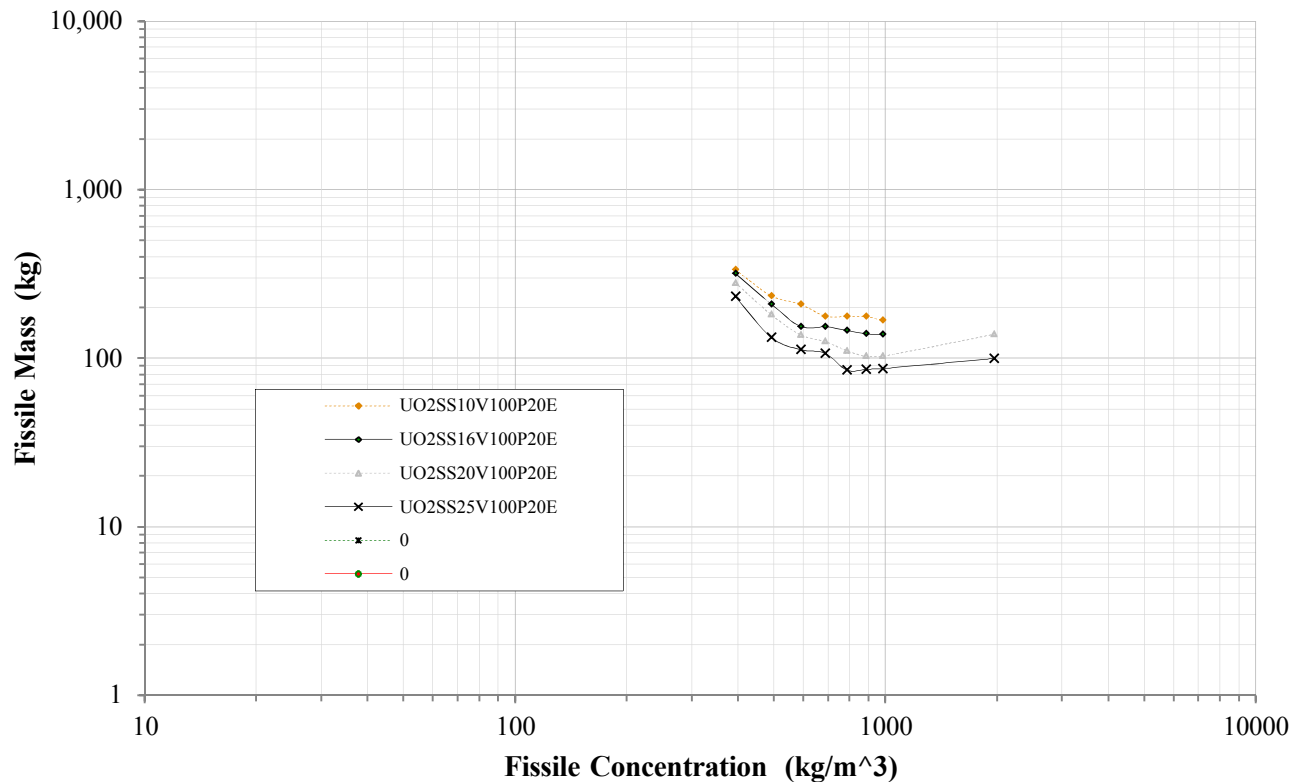
UO<sub>2</sub> (20% enriched), pure salt (variable porosity), pure water



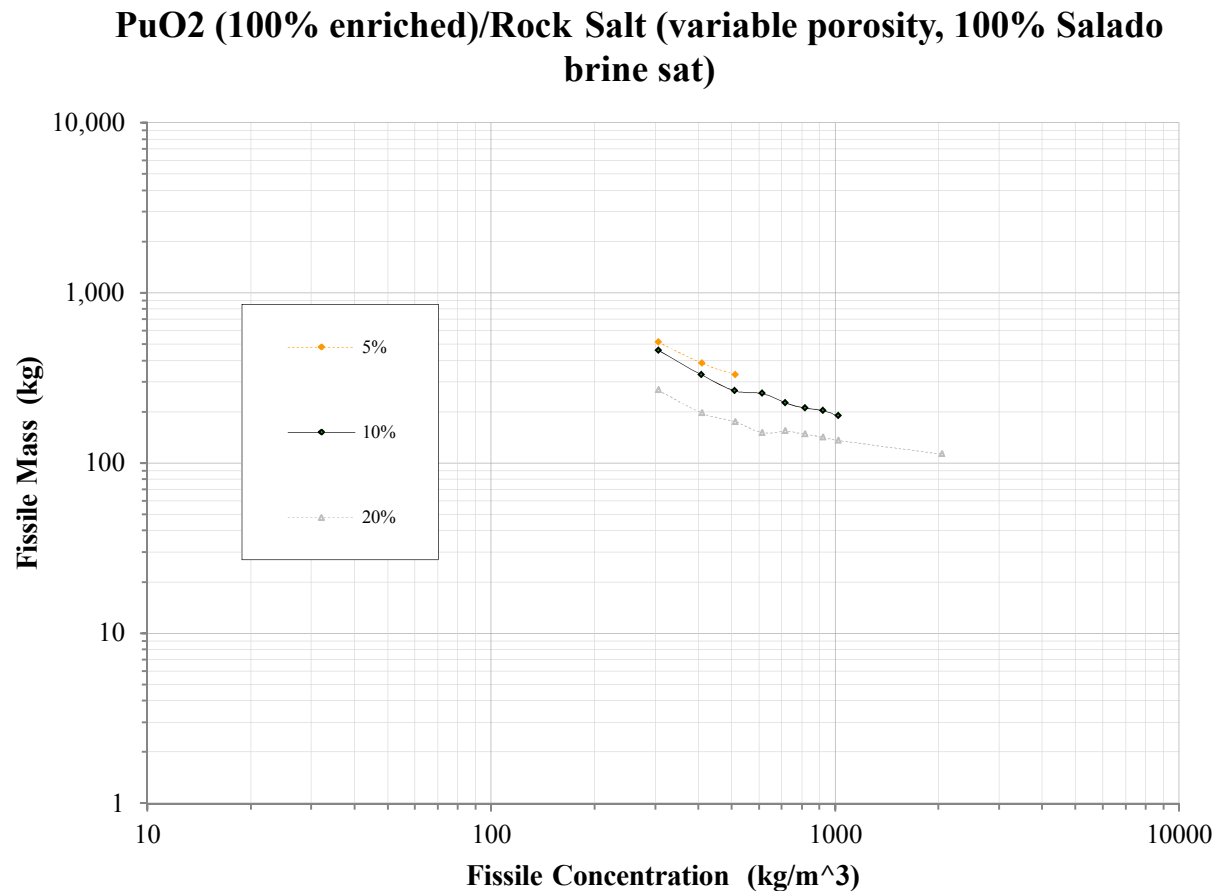
# Direct disposal of ER waste in a mined salt repository does not cause a criticality concern



S-Curve for UO<sub>2</sub> / RockSalt (variable porosity, 100% saturation, 20% enrich)



# Direct disposal of ER waste in a mined salt repository does not cause a criticality concern



# Current progress on ER criticality evaluation for disposal

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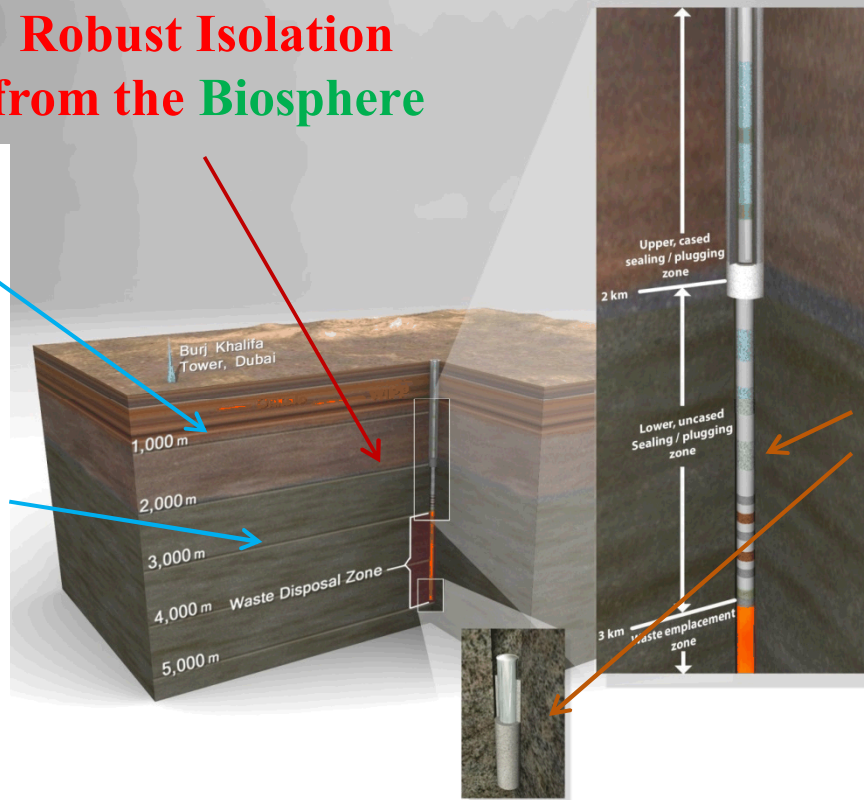


- **Criticality analysis of *degraded* in-situ ER waste within deep borehole**
  - Simulated as homogeneous case
- **Criticality analysis of intact in-situ ER waste within deep borehole (granite)**
  - Simulated as concentric cylinders
- **Characteristics of ER waste**
  - Identification of any inventory data gaps
  - Identification of thermal load
  - Identification of significant gamma lines

# Deep borehole disposal feasible concept for HLW from reprocessing



## Robust Isolation from the Biosphere



## Engineered Barriers

- Waste forms
- Waste packages
- Borehole seals (and DRZ)

## Natural System

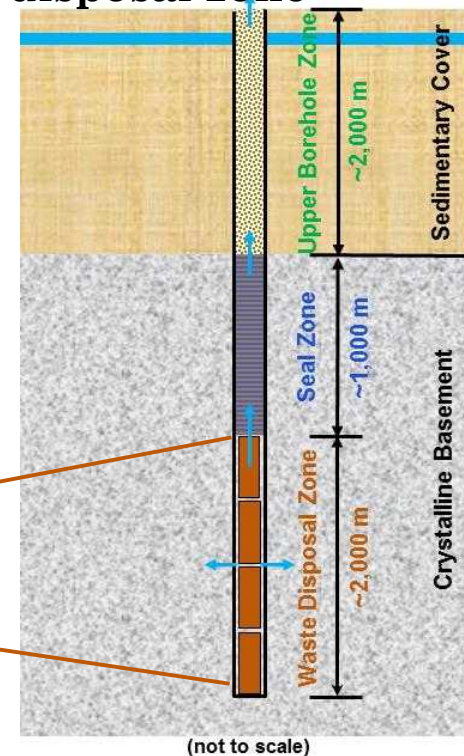
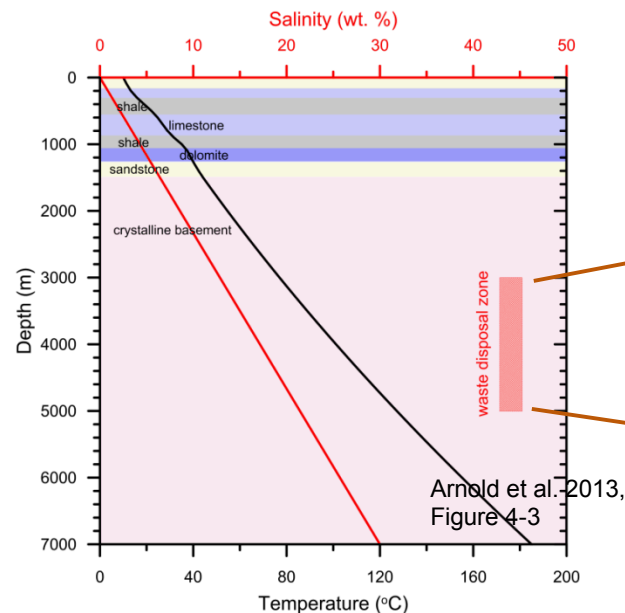
- Overlying Sediments
- Crystalline Basement
  - Low permeability and long residence time
  - Density stratification of saline groundwater opposes upward convection
  - Geochemically reducing conditions limit the solubility and enhance the sorption of many radionuclides



# Several features of deep borehole disposal help isolate waste

## ■ Crystalline Basement Host Rock

- Low permeability ( $k$ ) and porosity ( $\Phi$ )
- Reducing geochemical conditions at depth
- 110 °C moderate temperatures at center of disposal zone
  - 10°C at surface
  - Thermal gradient = 25°C/km
- High salinity and density gradient



# Simplified configurations of borehole criticality have been modeled

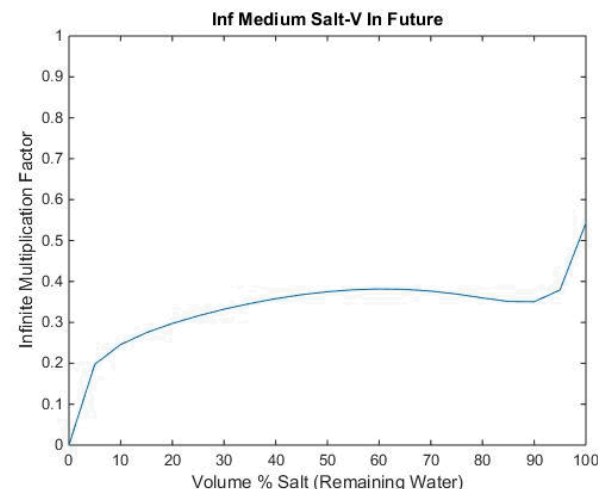
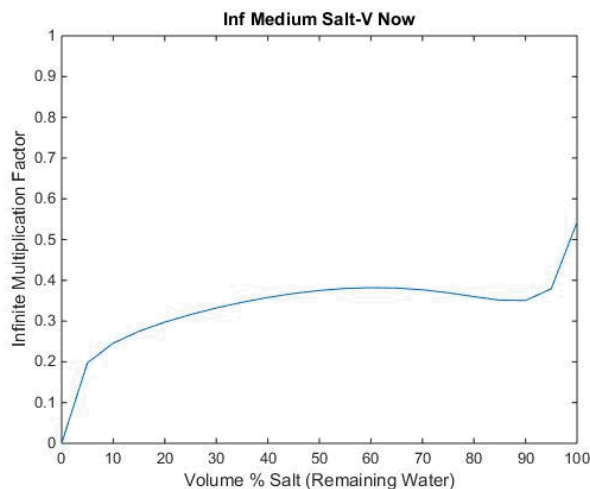
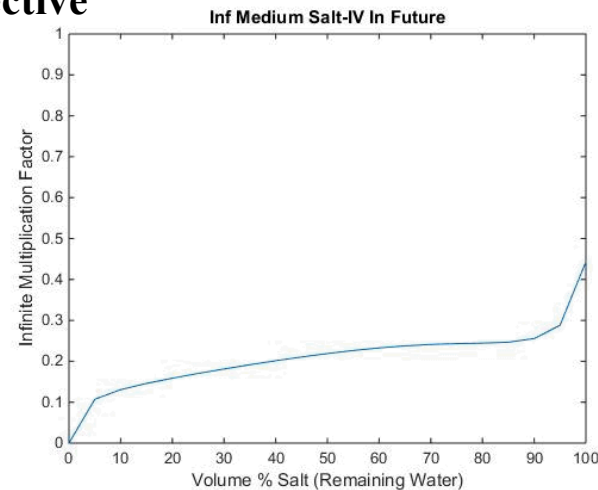
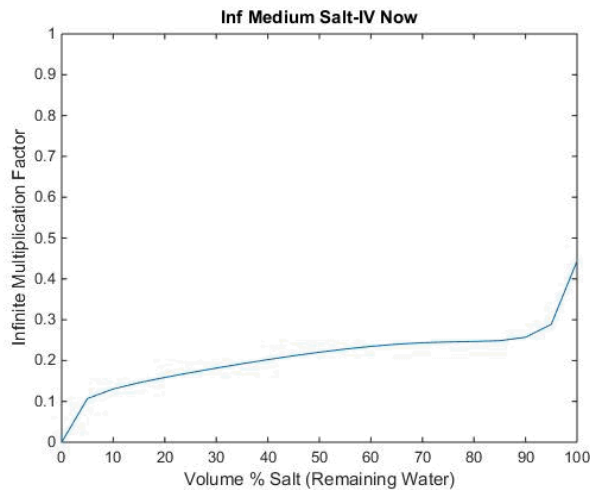


- Selected to model with CSAS (a one dimensional photon/neutron transport code)
- Fuel was first modeled as infinite homogeneous medium for degraded fuel
  - Pure water moderator was mixed with the fuel by volume fraction
- Fuel then modeled as infinite cylinders for intact fuel
  - One cylinder represented steel of canister and casing
  - 1.5 cm thick 304 SS shell
  - 5 cm radius to 50 cm radius
- Included natural uranium in granite 20 ppm
- Simulated current criticality potential and future potential
  - Future potential determined by removing short-lived (<100 yr half life)

# No criticality potential for all combinations of water/salt when modeled as infinite media



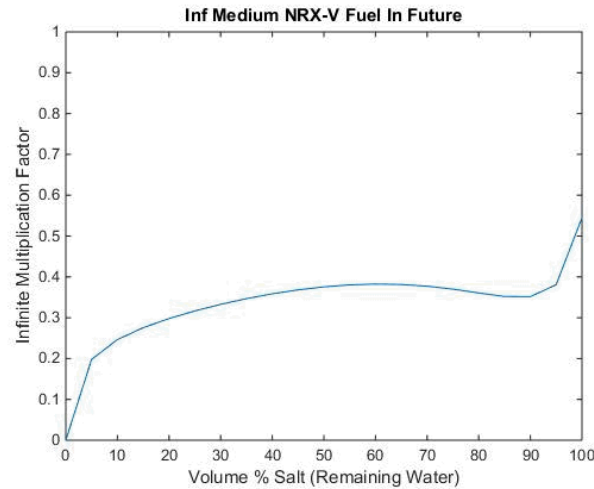
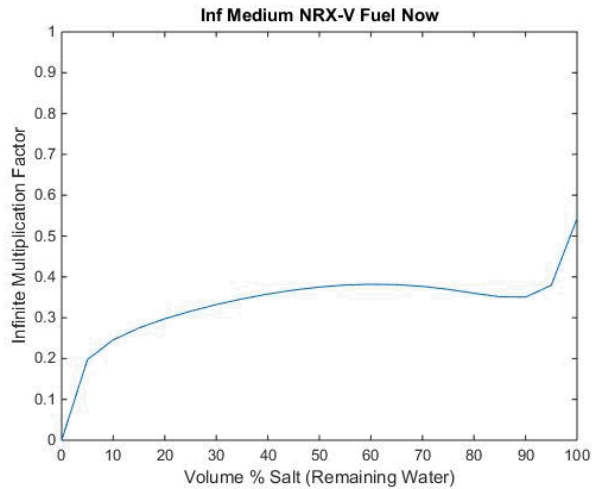
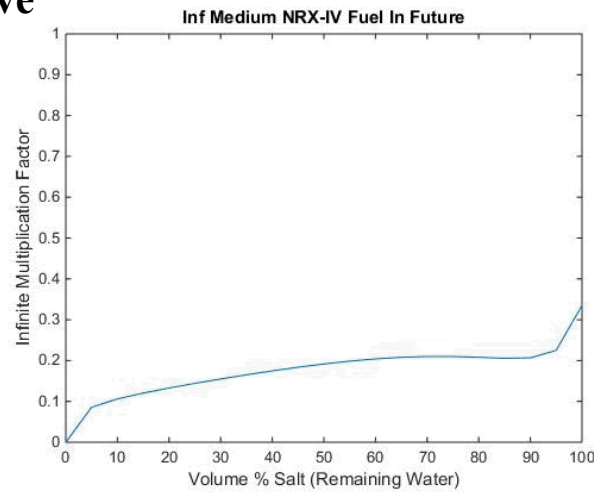
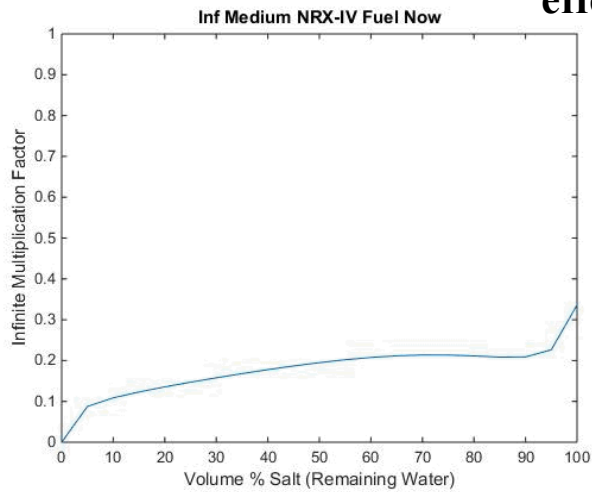
Infinite  $k_{\text{effective}} \ll 1$



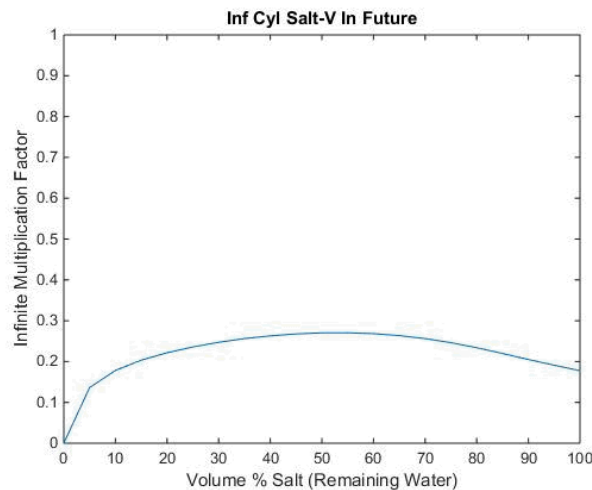
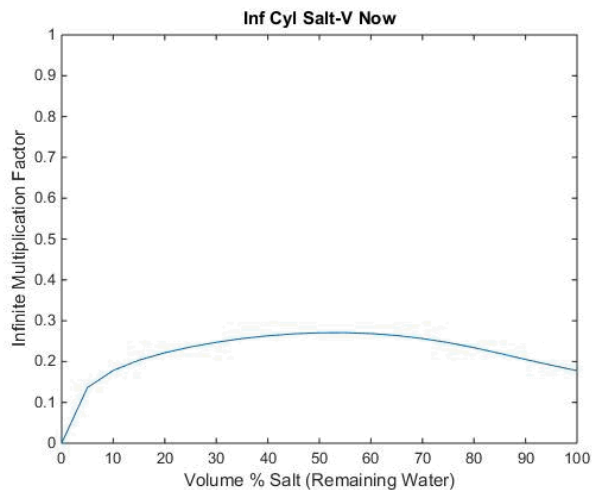
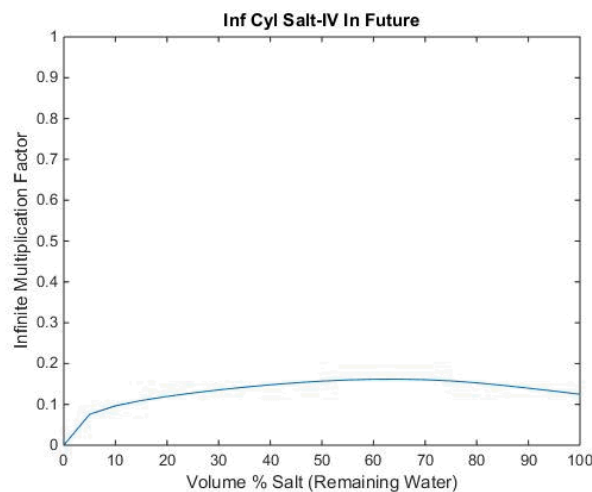
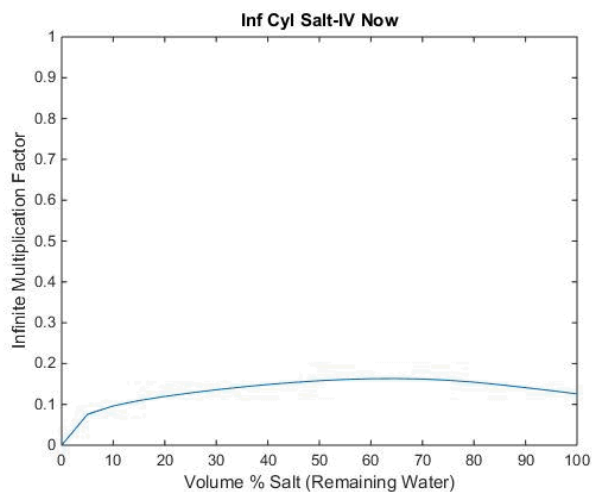
# Similar situation exists for NRX Fuel: No criticality potential



$k_{\text{effective}} \ll 1$



# Even less criticality potential for ER salt waste modeled as infinite cylinder with 304 SS casing



# Isotopic concentrations of ER waste seem to be missing some fission products

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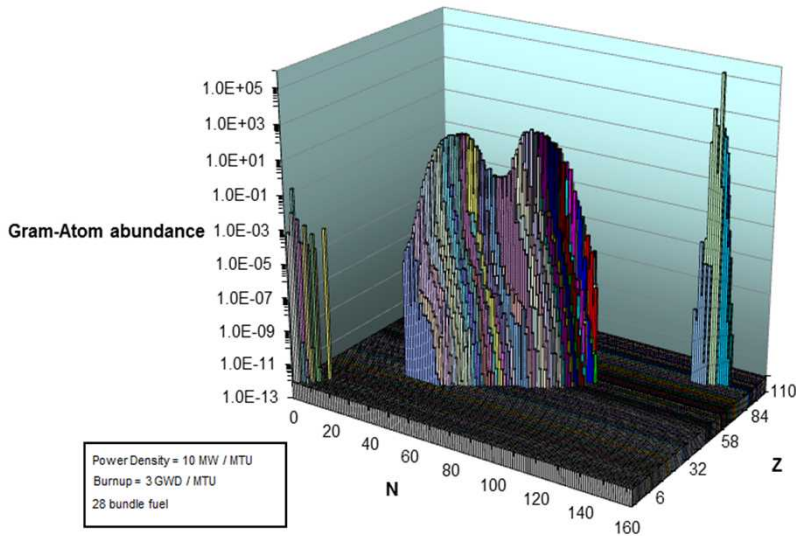


- Are they removed chemically in reprocessing?

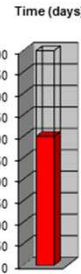
# Generic Spent Nuclear Fuel Signature (typical HWR & PWR SNF inventory)



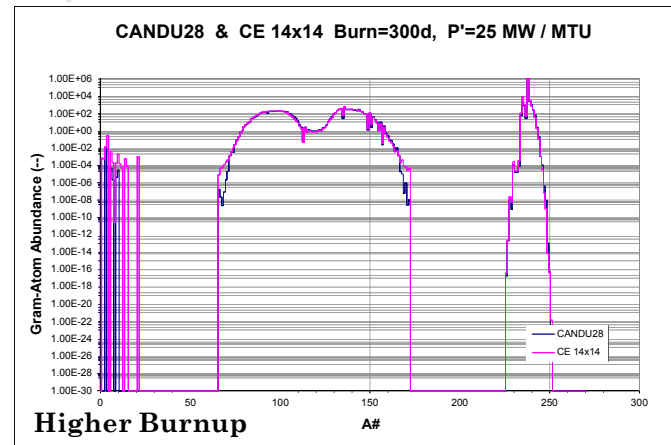
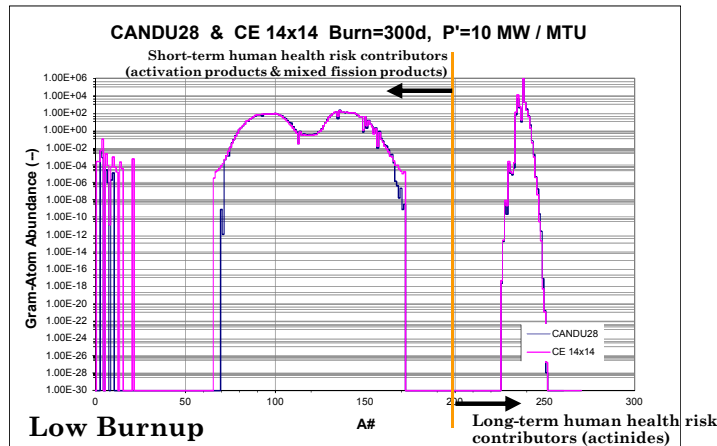
CANDU28 (HWR 0.711wt% fuel -- 300 day Burn)



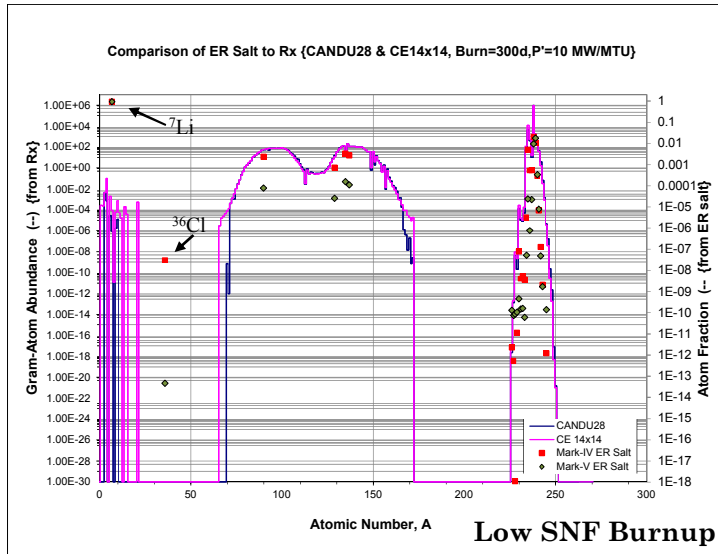
- **SNF has three components:**
  - Neutron Activation Products (may be a thermal load concern)
  - Fission Yield Products (gamma concern)
  - Actinide Tail (thermal load and FGE concern)



- The nuclide signature of SNF from different reactor types are similar – many differences occur in the actinide FGE and with short-lived FYPs

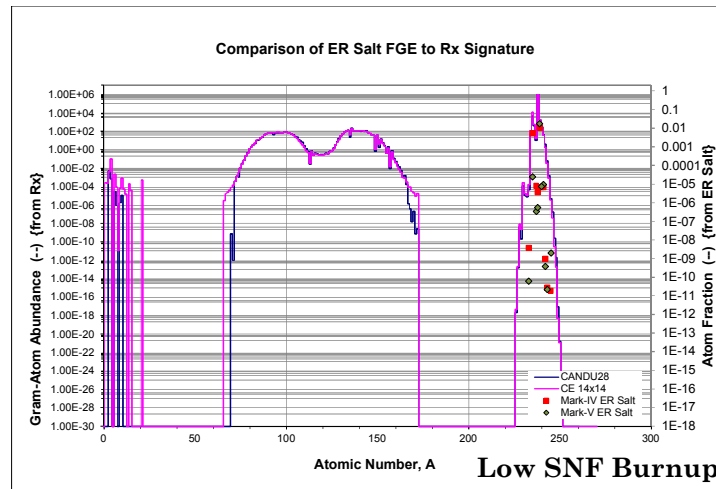


# ER Salt Waste Signature (comparison to typical HWR & PWR SNF)



## • ER Salt Waste key attributes:

- Significant quantities of Li-7
- Fission Yield Products  
(due to radioactive decay and chemical separation process)
- Actinide Tail  
(thermal load and FGE concern)

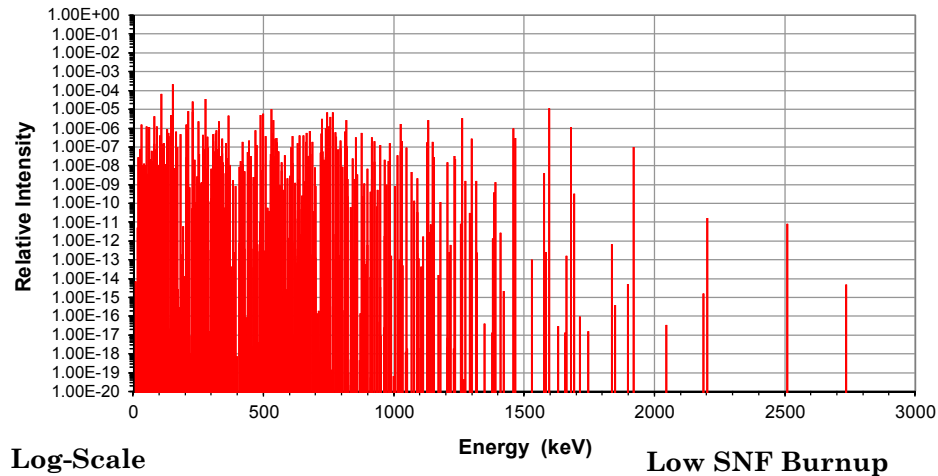


- Data gaps in the ER nuclide signature for FGE and FYP gamma lines needs to be checked

# ER Salt Waste Gamma Lines

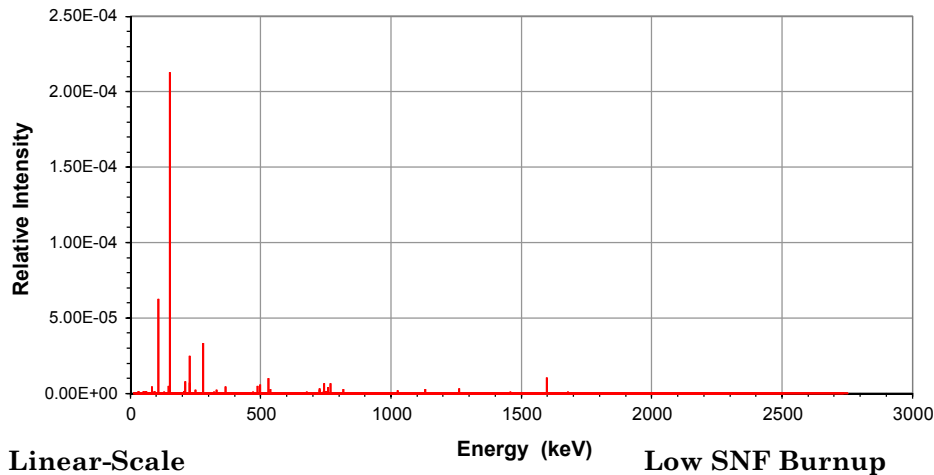


HWR -- Gamma Spectrum (20080623)



- **Example INRAD (intrinsic radiation) from HWR SNF**

HWR -- Gamma Spectrum (20080623)

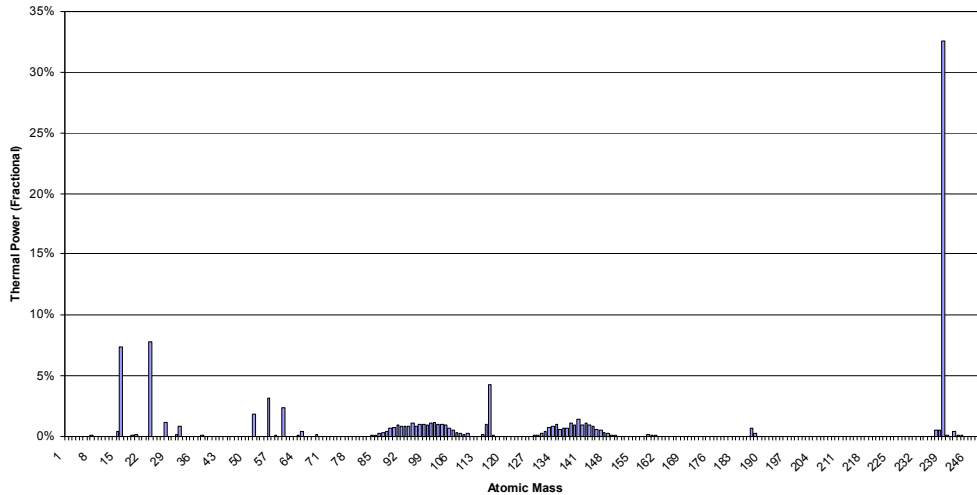


- **In Progress – INRAD for ER Salt waste will be determined when data gaps in ER nuclide signature are resolved.**

# SNF Thermal Signature



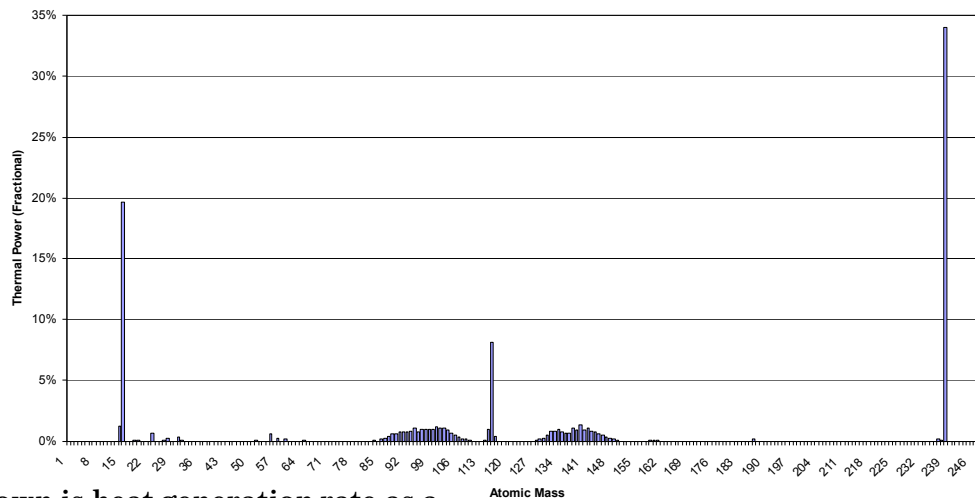
PWR (1000 Days @ 30 MW(t))



- Example thermal load signature from SNF

PWR

LMFBR (1000 Days @ 30 MW(t))



LMFBR

- In Progress – Thermal load signature for ER Salt waste will be determined when data gaps in ER nuclide signature are resolved.

(data shown is heat generation rate as a function of mass number)



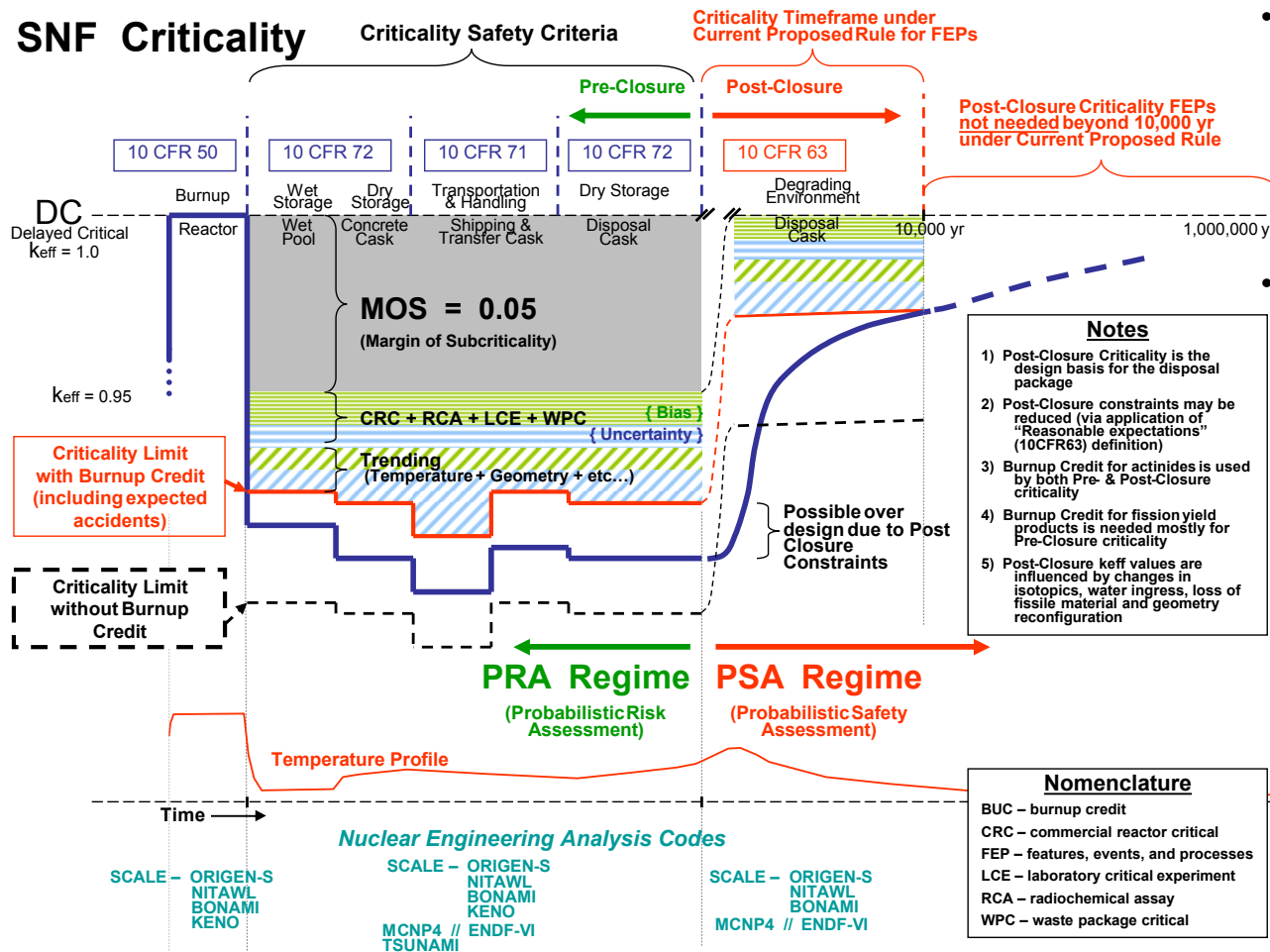
- **Work yet to perform on transportation casks**
- **Direct disposal of ER waste in a borehole does not cause a criticality concern primarily because of the limited physical dimensions**
- **ER inventory discrepancies need to be understood**

# Backup slides

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# SNF Criticality Safety Criteria



- SNF is subject to several safety criteria for storage, transport, and disposal.
- Key analysis for repository disposal is the FEPs (features, events, and processes) screening analysis – needed to reduce criticality modeling in the repository PA (performance assessment).

# For ER waste disposal, criticality evaluated within probabilistic framework

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- **Criticality is feature, event, or process (FEP) that is usually omitted from a performance assessment of a repository**
- **Guidance on how to treat human intrusion has evolved from that specified in 1985/1993 generic EPA standard to that specified in 2008 site-specific standard applying to Yucca Mountain**
- **Based on the site-specific regulation, human intrusion what not be included in a screening for the criticality FEP**
- **Hence, criticality evaluation mostly confined to the repository**
  - **The EBS for a mined salt repository and its limited ability to move fissile material**
  - **The borehole for deep borehole disposal**
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# Similar situation for NRX Fuel when modeled as Infinite Cylinders

