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Perspectives on Dual-Purpose Canister Direct Disposal Feasibility Evaluation

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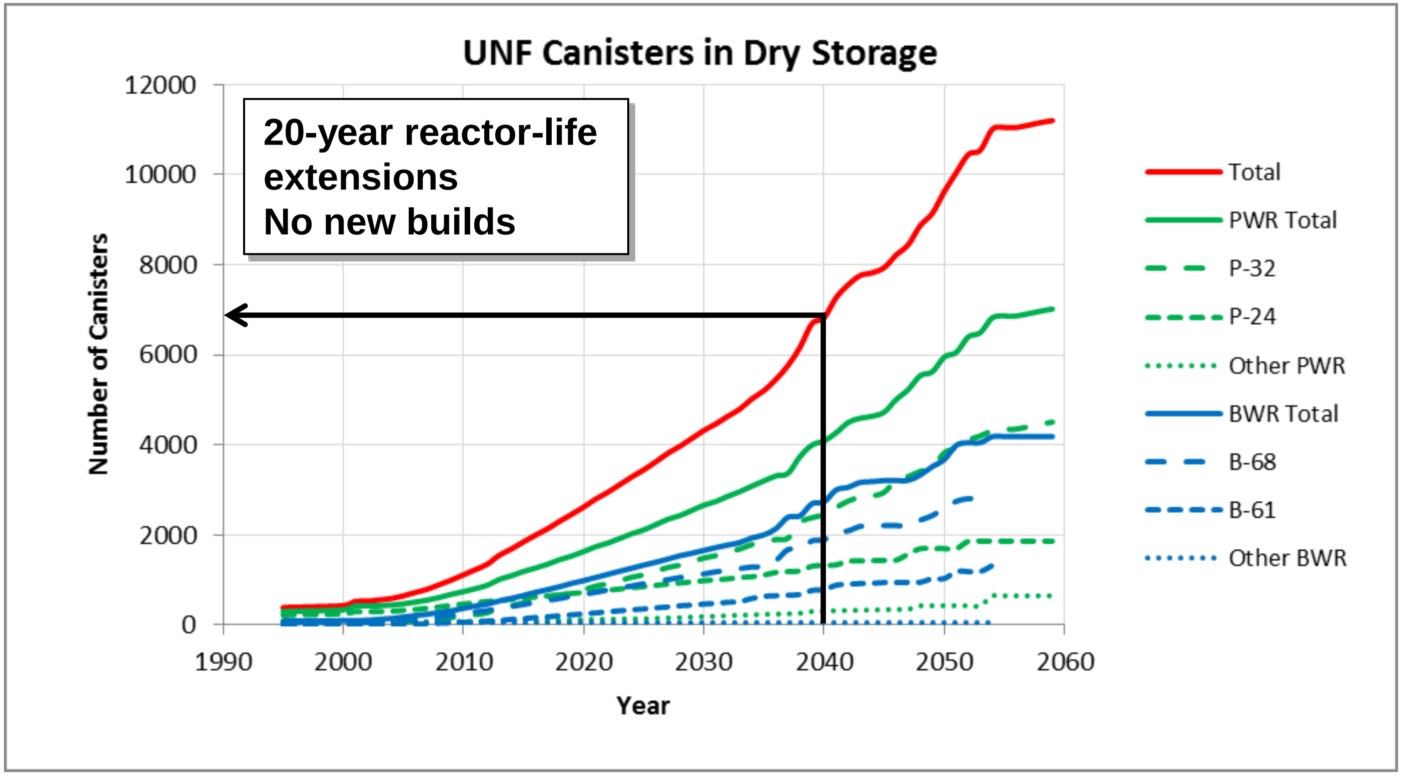
Context

This is a technical presentation that does not take into account the contractual limitations under the Standard Contract. Under the provisions of the Standard Contract, DOE does not consider spent fuel in canisters to be an acceptable waste form, absent a mutually agreed to contract modification.

Dry Storage Projections (TSL-CALVIN)



- 2035: > 50% of commercial used fuel in the U.S. will be stored in ~7,000 DPCs
- 1,900 canisters now, >10,000 possible
- 160 new DPCs (~2,000 MTHM) per year
- At repository opening (2048) the oldest DPC-fuel will be >50 years out-of-reactor
- Reactor and pool decommissioning will accelerate transfers to DPCs

Technical Evaluation of DPC Direct Disposal Feasibility

Q: Why evaluate technical feasibility of direct disposal of large dual-purpose canisters?

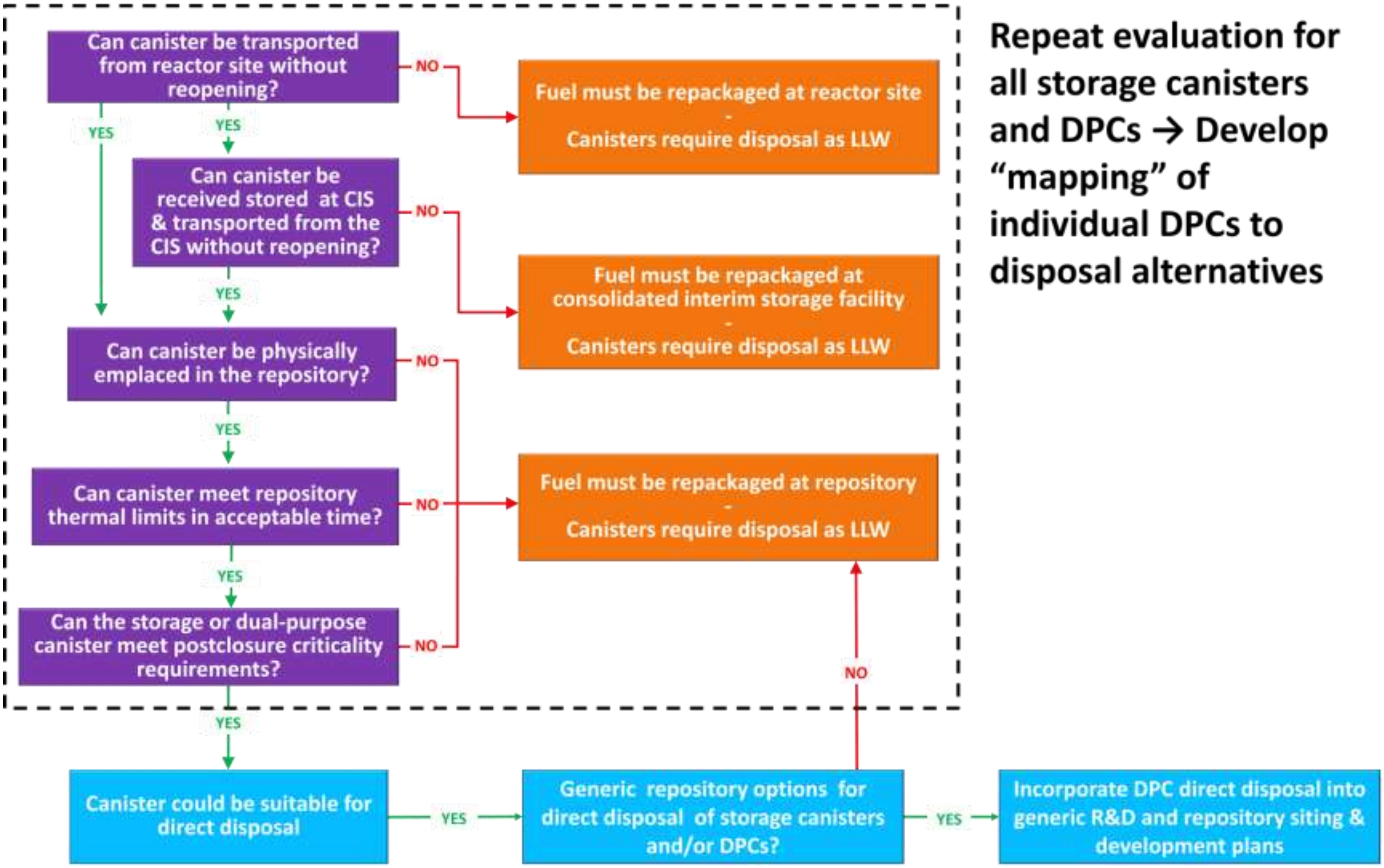
A: Potential for

- **Less fuel handling**
- **Simpler UNF/SNF management (facilities, siting, etc.)**
- **Lower cost**
  - **Re-packaging cost (operations, new canister hardware)**
  - **10,000 waste packages for U.S. SNF vs. up to 9X that many for smaller packages**
- **Lower worker dose**
- **Less waste (e.g., not disposing of existing DPC hardware)**

Key Technical Assumptions for DPC Direct Diposal Feasibility Evaluation

- Complete disposal operations (i.e., panel closure) at/before fuel age of 150 years from reactor discharge
- DPC-based waste package size: 2 m dia. × 5 m long, and 80 MT
- Waste package + shielded transporter: ≥ 175 MT
- Fuel and canister condition will be suitable for transport and disposal for 100 years from reactor discharge
- DPCs will be placed in disposal overpacks
- Regulatory context for disposal similar to 40CFR197 and 10CFR63
- Low probability and low consequence arguments may both be used to evaluate criticality

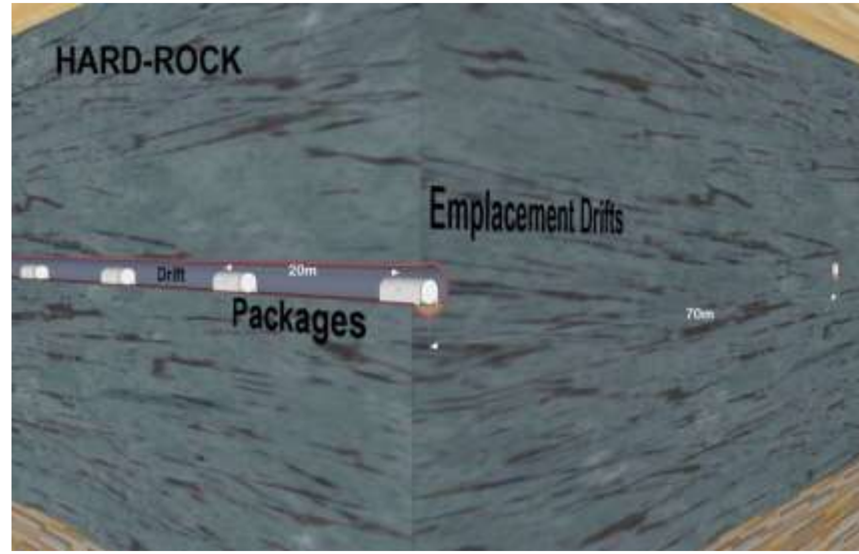
Path to Direct Disposal of Existing Storage-Only and Dual-Purpose Canisters

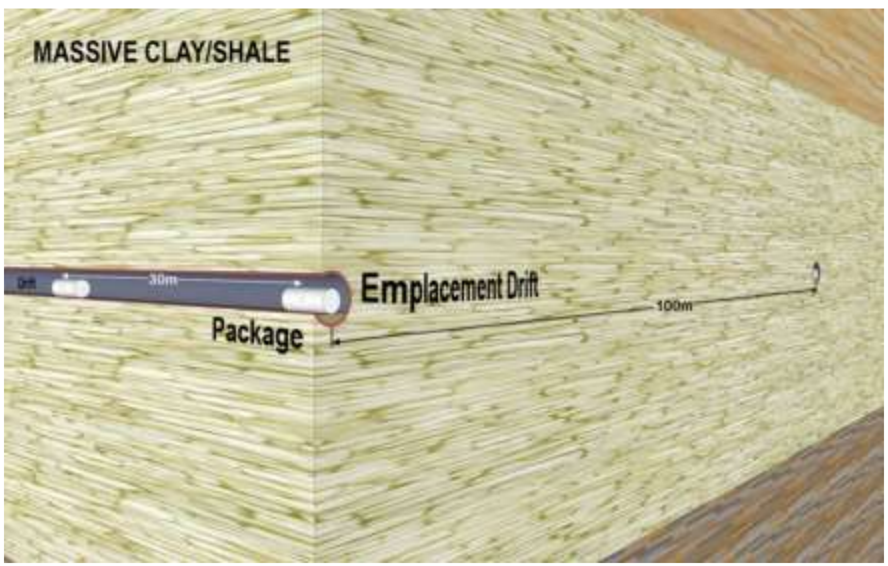


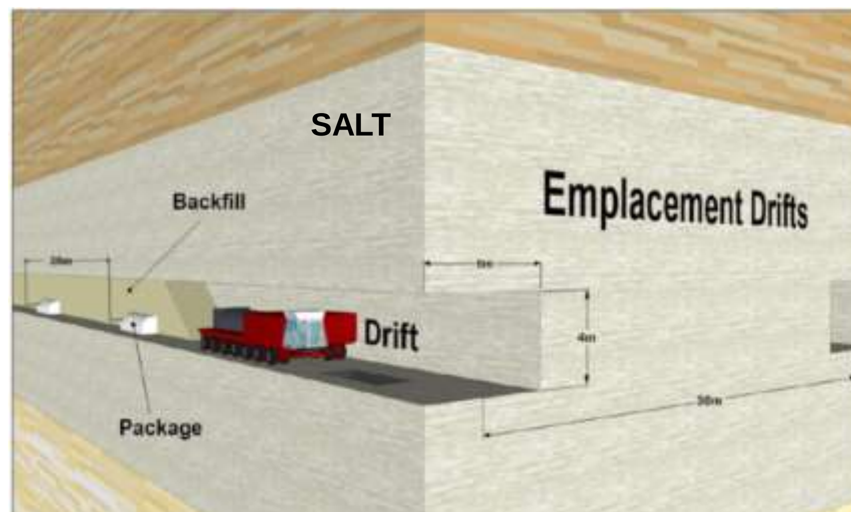
Repeat evaluation for all storage canisters and DPCs → Develop "mapping" of individual DPCs to disposal alternatives

DPC Direct Disposal Concepts

- **Engineering challenges are technically feasible**
- **Shaft or ramp transport**
- **In-drift emplacement**
- **Repository ventilation (except salt)**
- **Backfill prior to closure**







Source: Hardin et al. 2013. FCRD-UFD-2013-000171 Rev. 0.

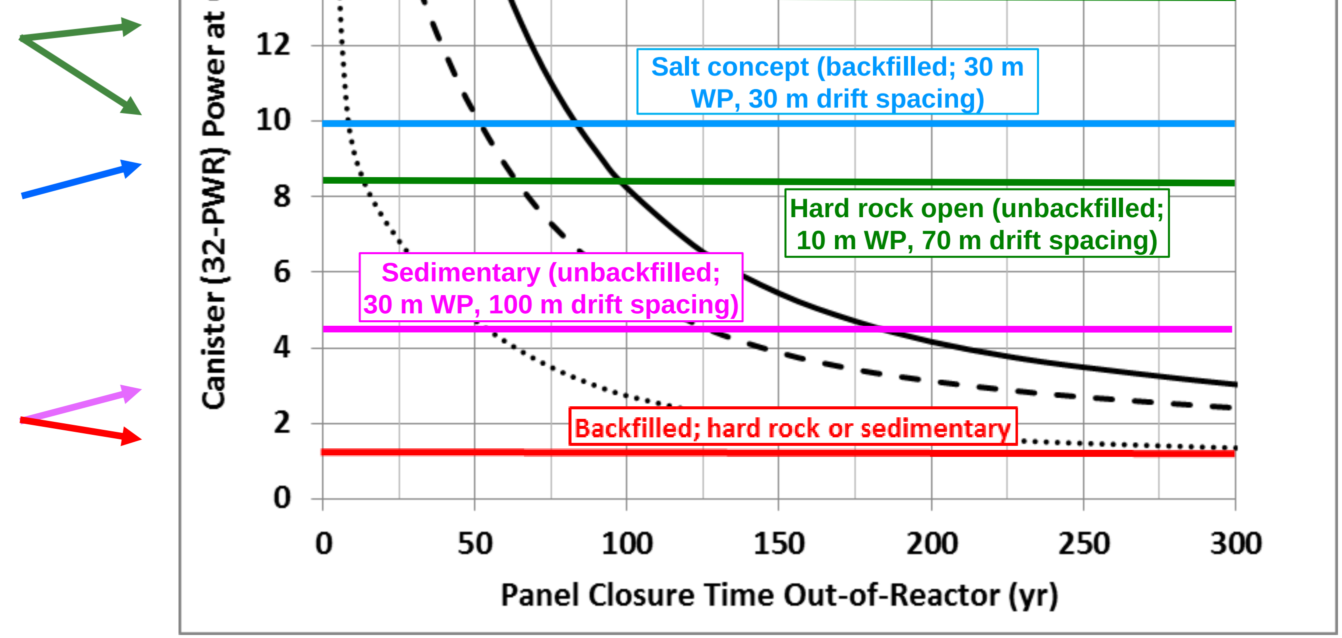
Time to Repository (Panel) Closure for Representative Disposal Concepts

32-PWR size packages

Hard rock concept (unbackfilled, unsaturated, with small and large spacings)

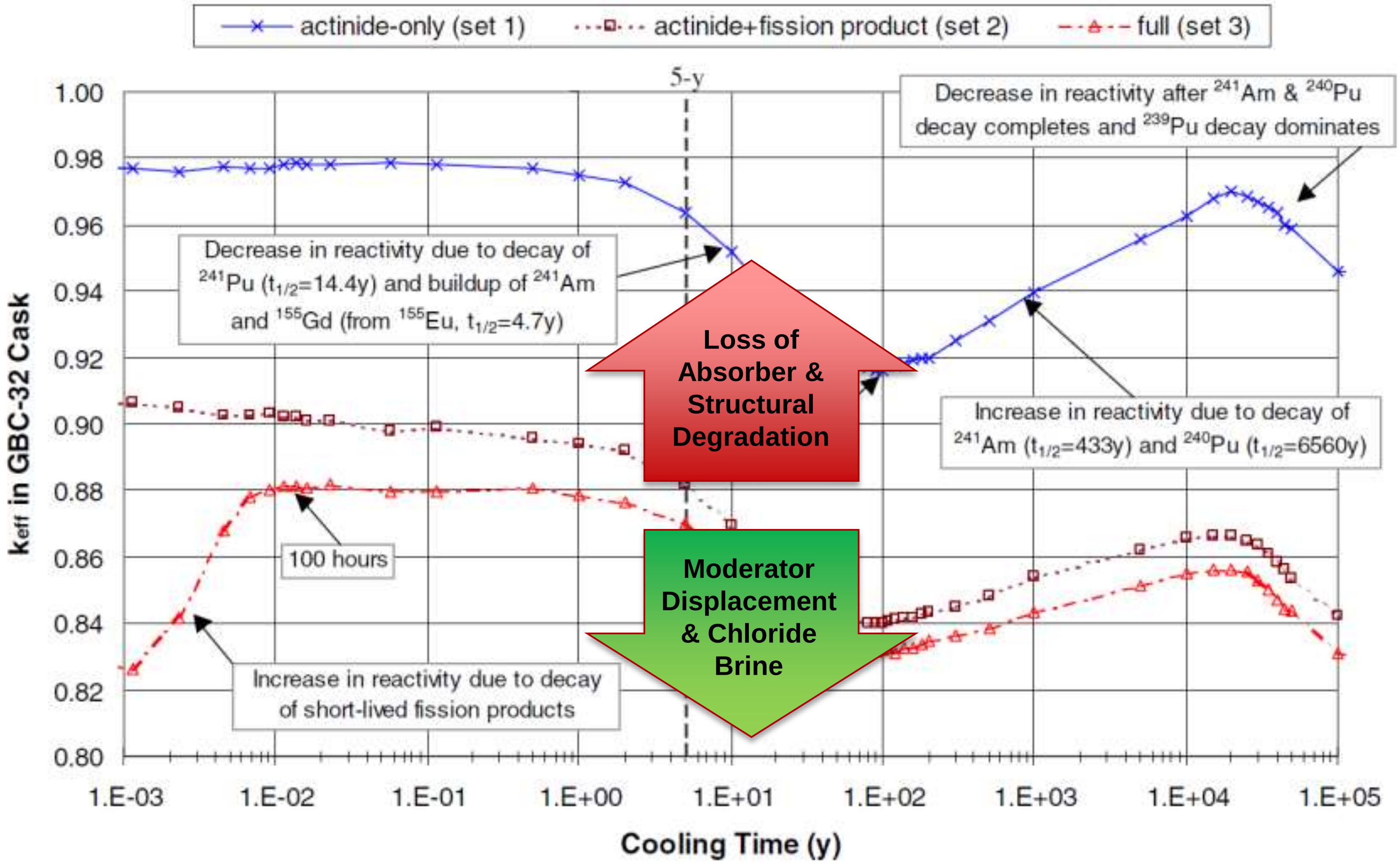
Salt concept

Clay/shale concept and any backfilled concept require much longer aging



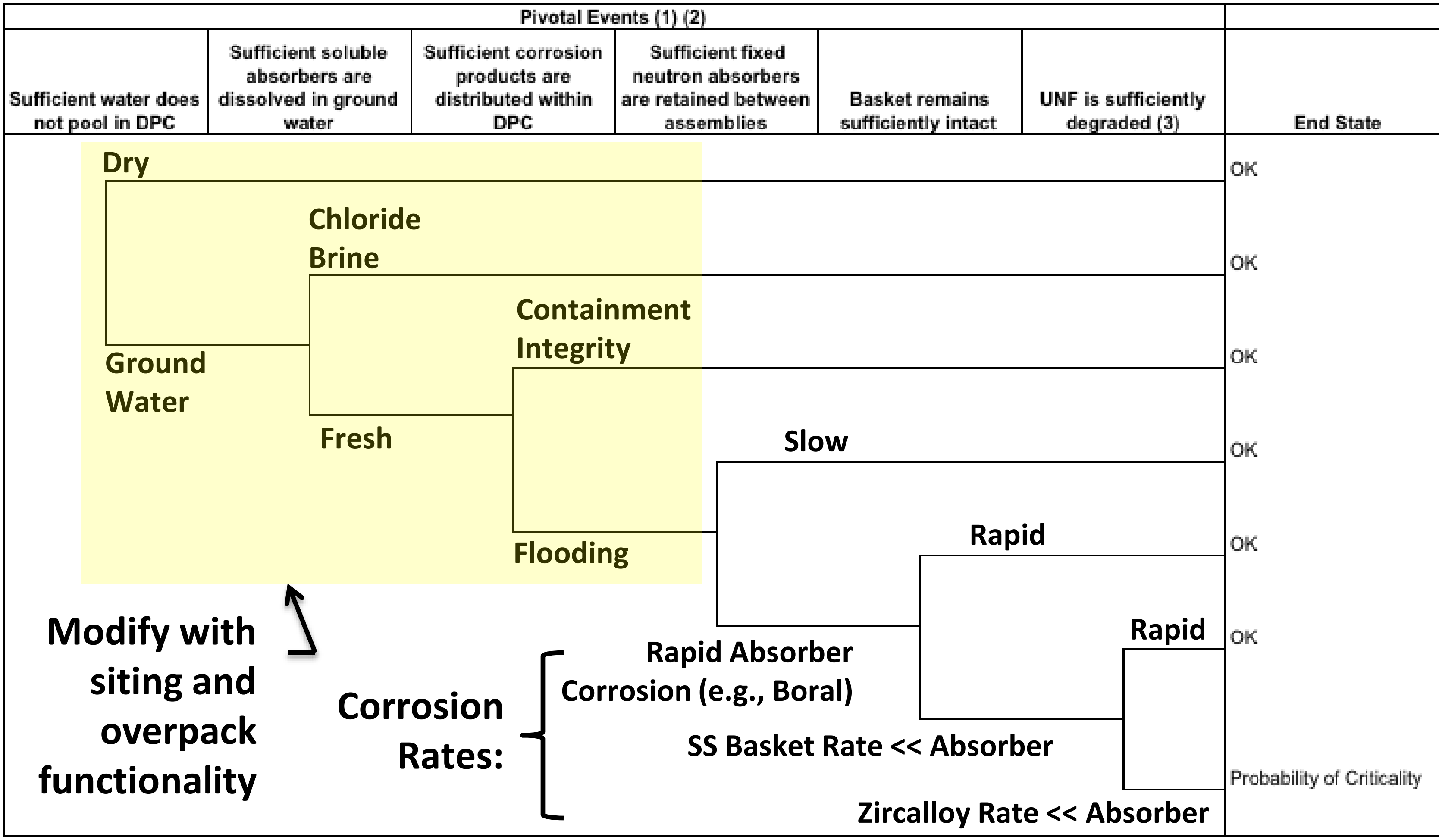
Based on: Hardin et al. 2013. *Collaborative Report on Disposal Concepts.* FCRD-UFD-2013-000170 Rev. 0.

Analysis of Postclosure Criticality - Summary



Generic burnup credit 32-PWR canister (cask) PWR fuel (4% enriched, 40 GW-d/MT burnup)
Original Figure: Wagner J.C. & C.V. Parks 2001. NUREG/CR-6781, Fig. 3.

Stylized Postclosure Criticality Event Tree



(1) These pivotal events could probabilistic, deterministic evaluations/judgments, or distributions
(2) Sufficiency is based on the envelope analyses discussed in Section 5. If these events are probabilistically developed, then inter-dependency must be taken into consideration
(3) Prior to any of the previous pivotal events (water pooling, loss of dissolved poisons, loss of moderator displacers, loss of fixed neutron poisons, basket degradation)

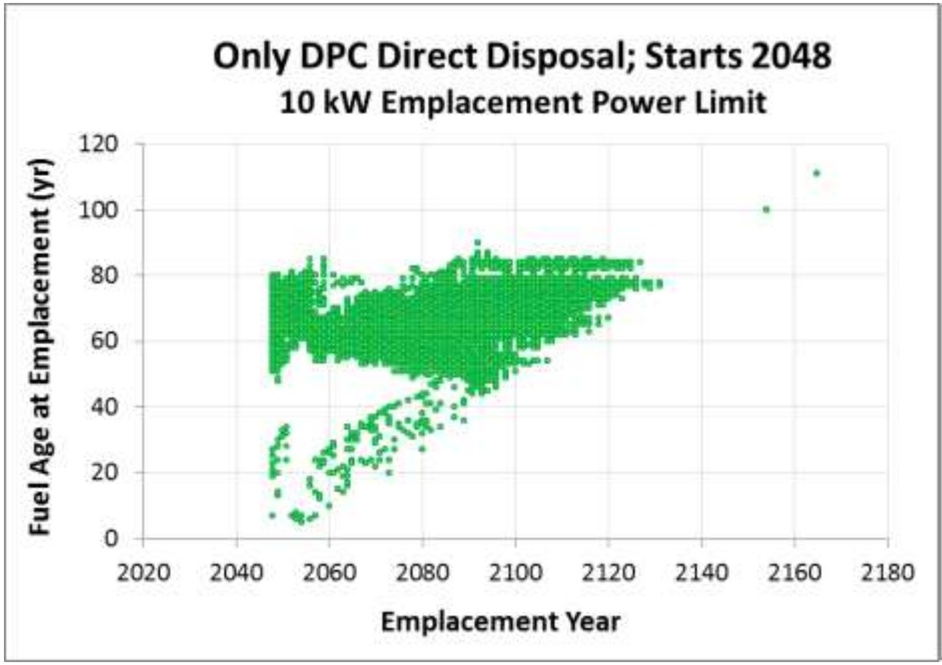
Original chart from Scaglione et al. 2014. *Criticality Analysis Process for Direct Disposal of Dual Purpose Canisters.* ORNL/LTR-2014/80. Oak Ridge National Laboratory.

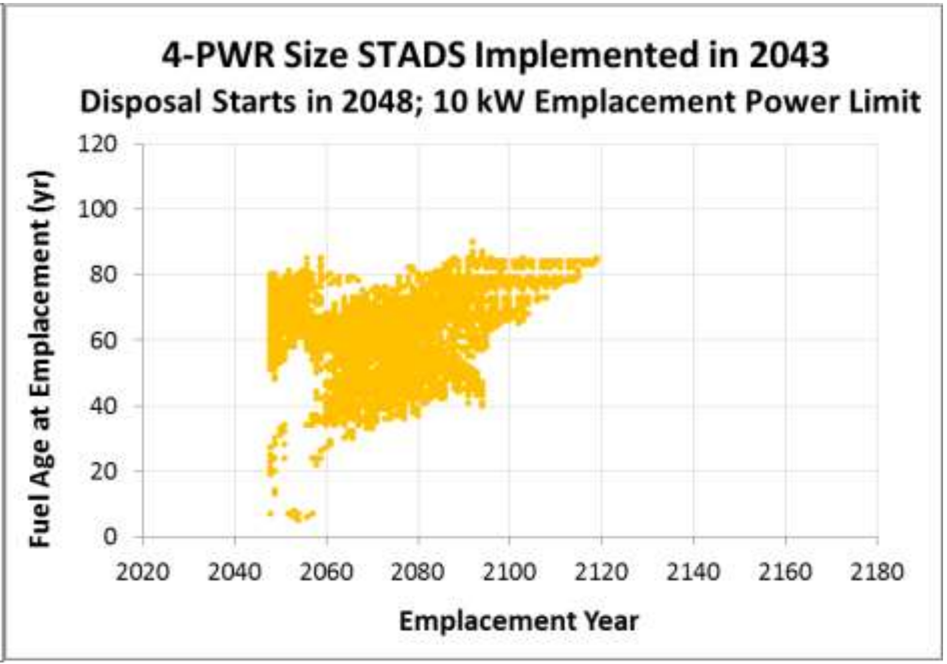
Possible DPC Direct Disposal, Re-Packaging and STAD Canister Strategies

STAD Canister ≡ Storage, Transport and Disposal, Multi-Purpose Canister	Existing Canister Designs			New Design
	Storage-Only Canisters: Re-Package→ Disposal	DPCs: Re-Package→ Disposal	DPCs: Direct Disposal	Operational Switch to STAD Canister at Power Plants
1. No near-term changes→ Re-package (*current path*)	√	√		
2. No near-term changes→ Maximize direct disposal (*evaluate*)	?		√	
3. Multiple modes of disposal→ Minimize re-packaging (*evaluate*)	?		√	√
4. Re-package→STAD canister full implementation	√	√		√

Fuel Age at Emplacement in a Repository

Compared to Re-Packaging in Small STADS



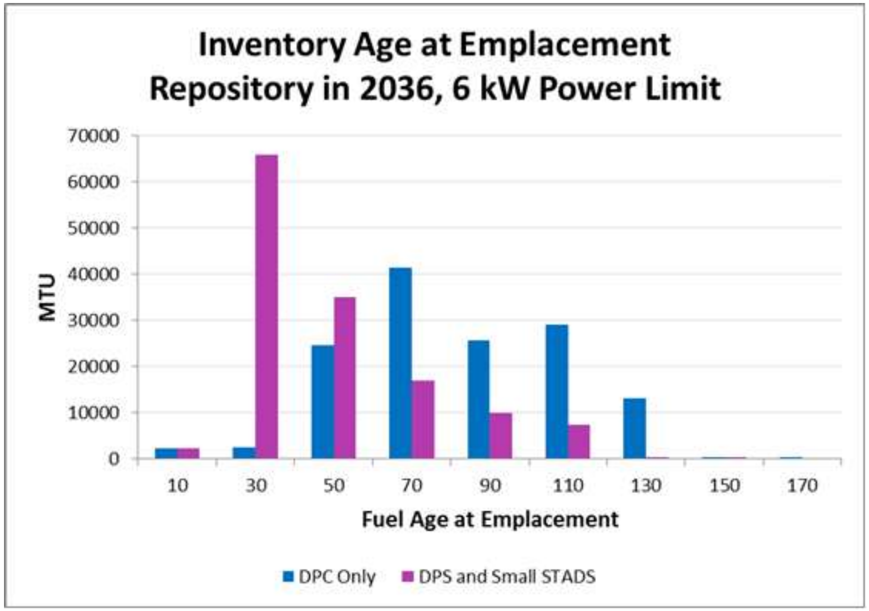


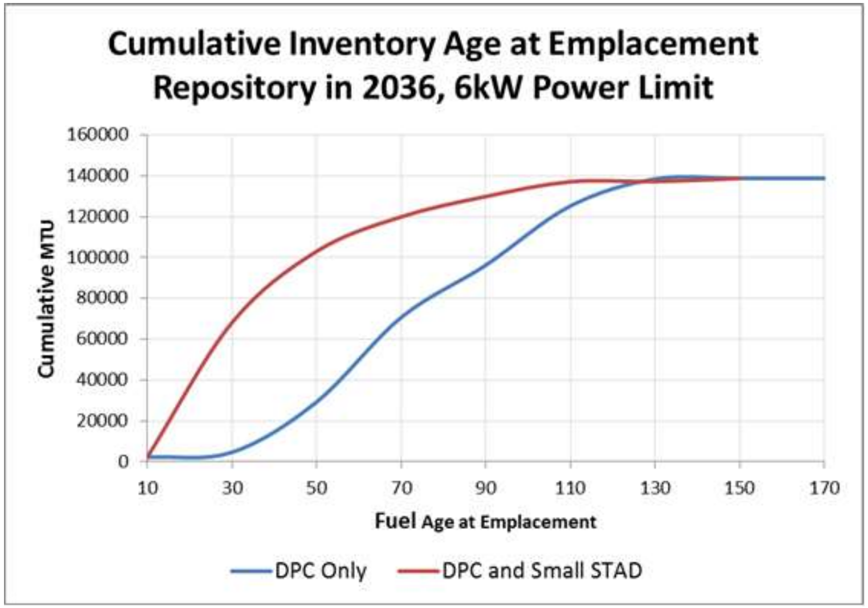
- **Plots show disposition of ~140,000 MTHM U.S. SNF**
  - For 10 kW limit, emplacement could be mostly complete by 2130
  - Smaller canisters accelerate disposal but SNF age at disposal is similar
- **Calculated using TSL-CALVIN (DRAFT)**

Timing of DPC Direct Disposal

Compared to Re-Packaging in Small STADS

Sensitivity Case: Accelerate Repository Opening to 2036





- **Limiting Fuel Age at Disposal is Sensitive To:**
  - Smaller canisters for earlier cooling to emplacement limits
  - Earlier repository opening date to take advantage of earlier cooling
- **Calculated using TSL-CALVIN (DRAFT)**

All options for DPC direct disposal are not the same:

- **Thermal Management**
  - Favors salt, hard-rock open concepts
- **Size and Operations**
  - Repository area ranges from 500 to 3,000 m^2/package, with zero to 100 years of repository ventilation
  - Favors salt and hard-rock open concepts
- **Postclosure Criticality**
  - Favors salt and very dry unsaturated settings
- **Human Intrusion**
  - Generally favors crystalline or hard rock

Therefore, waste packaging decisions (such as continued DPC use with the intention of direct disposal) could impact disposal system design and technical criteria for site evaluation.

What are some important implementation risks associated with DPC direct disposal?

Licensing Complexity: Safety analysis could require separate, conclusory calculations for >20 canister types (e.g., criticality calcs.) or even separate calcs. for each as-loaded canister.

Documentation: Utilities would need to produce data on fuel condition and loading, especially for as-loaded postclosure criticality analysis of degraded canisters.

Verification: Canister QA/QC (as performed by utilities and vendors) to include mis-load probabilities, could be important.

Criticality Consequence Analysis: For disposal environments with fresh groundwater, criticality consequence analysis could be needed.

Siting: Some geologic settings could involve more complex analysis to understand DPC-based waste package performance

Preliminary Technical Evaluation of DPC Direct Disposal Alternatives:

Summary and Conclusions

- **Disposal Alternatives**
  - Thermal, criticality, and engineering challenges were identified
  - Disposal concepts for salt, clay/shale and hard rock were developed
- **Thermal Results**
  - Repository (panel) closure possible for fuel age < 150 yr
  - R&D needs have been identified for concepts where clay-rich materials could see peak temperature > 100°C
- **Preliminary Logistics Results**
  - At 10 kW thermal limit, emplacement could be complete at 2130 with average throughput of 1,700 MTHM/yr
  - To significantly decrease fuel age at emplacement, early repository opening and STAD implementation (smaller canisters) are needed

Preliminary Technical Evaluation of DPC Direct Disposal Alternatives:

Summary and Conclusions, cont.

- **Criticality Scoping Results**
  - "Extra" reactivity margin is available using burnup credit analysis with as-loaded assembly information
  - Preliminary results show some, but not all, DPCs could be sub-critical for the degraded cases defined
  - Saline water (^{35}Cl > seawater) could provide significant neutron absorption

Preliminary results indicate DPC direct disposal could be technically feasible, at least for certain concepts. Cost savings could be realized compared to re-packaging, and further analysis is underway.

DPC Direct Disposal Feasibility Evaluation Technical R&D Priorities:

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- **Postclosure Criticality**
  - Prevalence of high-chloride groundwaters in different geologic settings
  - In-package canister/basket degradation, chemistry and configuration model
  - Overpack reliability
- **Waste Isolation/Performance Assessment**
  - System models that discern DPC vs. purpose-built canister performance
  - Supporting process models for thermally driven coupled processes
- **Concept Development & Thermal Management**
  - Cavern-retrievable or vault-type concept development
  - High-temperature backfill (→ 200°C)
  - Sinking of heavy packages in plastic media such as salt and claystone
- **Engineering Feasibility, Operational Safety & Cost**
- **Fillers**