SAND2016-2958PE

# Used Fuel Disposition R&D Campaign

## Preliminary Design Concepts Work Package Status Update

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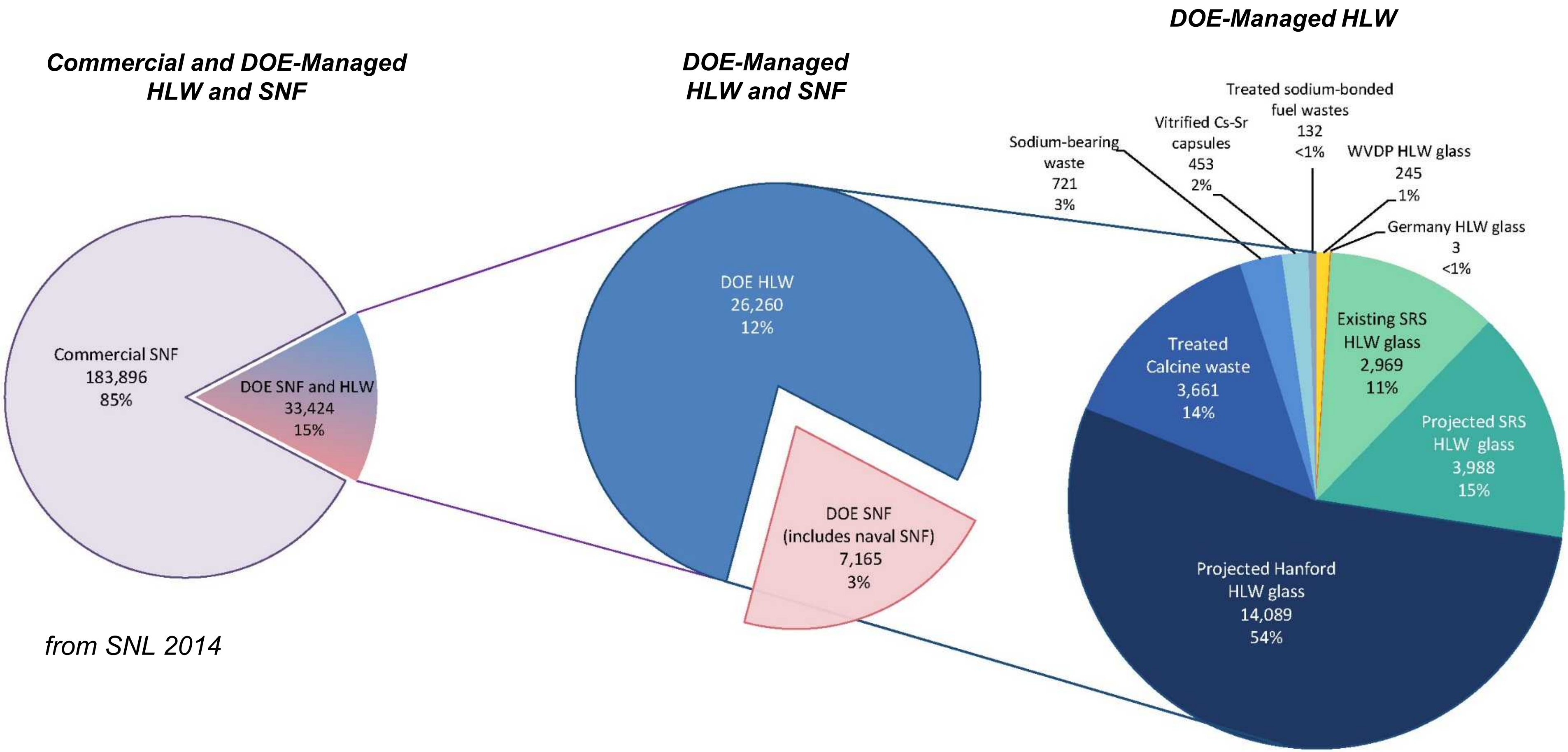
# Used Fuel Disposition

## 80% of DOE-Managed HLW volume is glass

*Projected volumes in m$^3$*




*from SNL 2014*

# Used Fuel Disposition

Table 3. Waste groups and pertinent characteristics for SNF in the US nuclear waste inventory (source: SNL 2014)

| Waste Group | Description | Waste Form | Waste Package Dimensions | [b] Number of Waste Packages | [b] Avg. thermal output per waste package |
|---|---|---|---|---|---|
| [a] WG1 | CSNF in PBC | [d] Purpose-built canister (PBC) | | | <25 kW[c] |
| | | Borehole | 10.6” dia by 181.1” | 470,063 | |
| | | Small | 32.3” dia by 196.9” | 89,364 | |
| | | Medium | 50.8” dia by 202.0” | 31,163 | |
| | | Large | 63.0” dia by 202.0” | 16,924 | |
| [a] WG2 | CSNF in DPC | Dual-purpose canister (DPC) | 98” dia. by 197” to 225” | 11,413 | <25 kW[c] |
| WG5 – Metallic Spent Fuels | Heterogeneous mix of DSNF | Multi-canister Overpack (MCO) | 24” dia by 166.4” | 413 | 500W or less |
| WG6 – Sodium bonded fuels | | | | | |
| WG7 – DOE oxide fuels | | | | | |
| WG9 – coated particle spent fuels | | 18x10 | 18” dia by 10’ | 1,506 | |
| | | 18x15 | 18” dia by 15’ | 1,474 | |
| | | 24x10 | 24” dia by 10’ | 133 | |
| | | 24x15 | 24” dia by 15’ | 27 | |
| WG10 – Naval fuel | Naval SNF | Naval SNF canister | 66” dia by 187” | 90 | 11.8 kW limit |
| | | | 66” dia by 201.5” | 310 | 4.25 kW avg. |

[a] WG1 and WG2 are not under current consideration as DOE-Managed HLW and SNF. These WG’s are included merely for the purpose of comparison between CSNF and DOE-Managed SNF.
[b] Year 2048, if projected. Thermal output data correspond to thermal output per waste package in the year 2048.
[c] Stipulated by regulation to be <25kW
[d] Assumes only one size PBC is used for all the CSNF waste, such that the number of waste packages (solely for CSNF in PBC’s) corresponds to the number of PBC’s, all of a particular size, that would be needed for all CSNF. For example, if all CSNF were to be disposed of in borehole-sized PBC’s, 470,063 of these canisters would be needed to contain all of the CSNF waste.

# Used Fuel Disposition

***SRS Glass***

| | |
|---|---|
| *39 % of canisters* | *< 50 W* |
| *6.1%* | *50–100W* |
| *51.4%* | *100–220W* |
| *3.5%* | *220–300W* |

***Hanford Glass***

| | |
|---|---|
| *83.9% of canisters* | *< 50 W* |
| *11.1%* | *50–100W* |
| *4.7%* | *100–220W* |
| *0.3 %* | *220–300W* |

***All glass***

| | |
|---|---|
| *72.2% of canisters* | *< 50 W* |
| *7.4%* | *50–100W* |
| *19.1%* | *100–220W* |
| *0.2%* | *220–300W* |
| *1.1%* | *300-500W* |

*Data from Carter et al. 2013*



| Waste Group | Description | Waste Form | Waste Package Dimensions | [a] Number of Waste Packages | [a] Avg. thermal output per waste package |
|---|---|---|---|---|---|
| WG3 – HLW Glass | Existing SRS HLW Glass | SRS canister | 24" dia by 118" | 3,339 | 30 W |
| | Existing West Valley HLW Glass | WVDP canister | 24" dia by 118" | 275 | 238W |
| | FRG HLW Glass | FRG canister | 11.8" dia by 47.2" | 34 | [b] 950W |
| | Projected Hanford HLW Glass | Hanford canister | 24" dia by 177" | 10,586 | 29W |
| | Projected SRS HLW Glass | SRS canister | 24" dia by 118" | 4,485 | 30W |
| | *Calcine Waste (vitrified)* | Vitrified Calcine Waste Canister | 24" dia by 118" | 11,400 | 1.2-15.4 W |
| | *Cs/Sr capsules at Hanford (vitrified)* | Vitrified Cs/Sr waste in Hanford HLW Glass canister | 24" dia by 177" | 340 | 905W |
| WG4 – other Engineered waste forms | [c] *Metallic sodium bonded* | Glass-bonded sodalite from EMT | 24"dia by 118" | 64 | 2,240W |
| | | INL Metal waste from EMT | 24"dia by 118" | 64 | neglible |
| | [d] *Calcine waste Hot Isostatic Pressing (HIP – A)* | HIP canister (encloses 10 HIP cans) | 66" dia by 204" | 3,200 | 40-540W |
| | *Calcine waste (HIP – B)* | HIP canister (encloses 10 HIP cans) | 66" dia by 204" | 1,600 | 80-1080W |
| WG8 –salt, granular solids, powders | *Metallic sodium bonded* | Salt waste from EMT direct disposal canister | 24"dia by 118" | 64 | 2,240 W |
| | *Calcine Waste (Direct Disposal)* | Direct disposal canister | 26" dia by 121" | 4,900 | 2.4-36W |
| | Sodium bearing waste (SBW) at INL | SBW canister | 26" dia by 120" | 688 | 2.5W |
| | *Cs/Sr Capsules (Direct Disposal)* | Untreated in overpack/canister | 24" dia by 120" (6 capsules per canister) | Cs- 267<br>Sr - 121 | 800W<br>1,170W |

[a] Year 2048, if projected. Thermal output data correspond to thermal output per waste package in the year 2048.
[b] Final configuration not selected. The canisters listed in Table 4 could be disposed of individually or stacked 2 or 3 per container.
[c] Metallic sodium bonded fuels can be processed by electro-metallurgical treatment (EMT) to produce either 1) metal waste and glass-bonded sodalite or 2) metal waste and salt waste.
[d] An alternative to HIP-B, HIP-A includes calcine waste plus Si, Ti, and $CaSO_4$ to produce RCRA-compliant glass ceramic waste form.

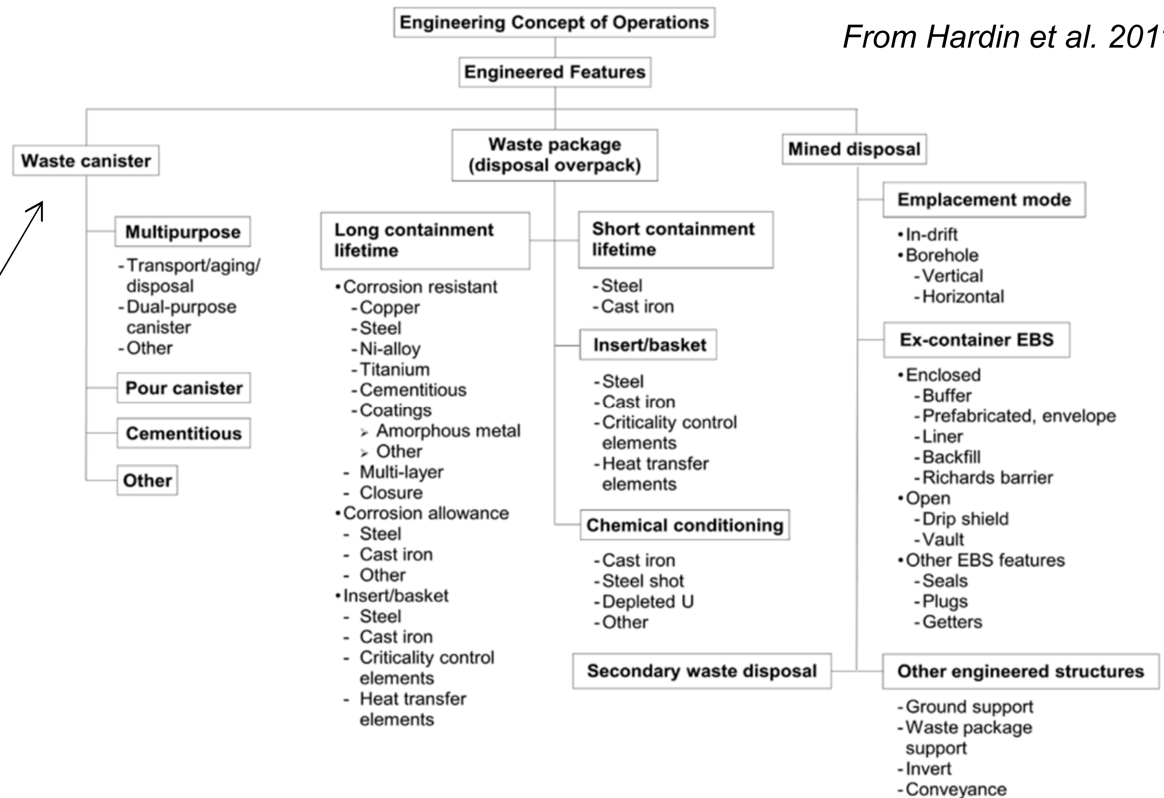
# Used Fuel Disposition

# Creating a Design Concept

*Inventory*
- *Dimensions*
- *Quantity*
- *Thermal output*

*Design Concepts*
- *Packing spacing*

*From Hardin et al. 2011*




*Disposal Media*

# Crystalline Rock D-Rep Design Considerations

- **Host Rock Constructability**
  - Excavation method, ground support, DRZ
  - Construction and sealing cost
- **Saturated Zone, Fractured-Rock**
  - Low-permeability backfill and seals needed
- **Nominal and Disturbed Performance**
  - Uncertainty in fractured-rock hydrology
  - Possible future glaciation
- **Natural Barrier**
  - Potentially old groundwater, small head gradients (nominal)
- **Engineered Barriers**
  - Clay-based buffer
  - Corrosion-resistant packaging (>>$10^5$ yr containment within buffer)
  - Extensive international R&D

# Crystalline-Rock D-Rep Disposal Concept

- **Multi-Container Overpack Strategy for HLW**
  - Fewer (<5,000) less costly, corrosion-resistant overpacks
  - Unshielded
- **In-Drift Axial Emplacement**
  - Minimize excavated volume, facilitate handling of heavy packages
  - Small package-package spacing (e.g., 2 m)
  - Backfilling strategy: Packages placed on plinths of compacted clay, then backfilled with pelletized clay
  - Pre-constructed buffer strategy: Each package location prepared with compacted clay blocks and a steel liner; packages slide into liner (e.g., NUHOMS)
- **Clay-Based Backfill and Sealing of Accesses**
- **Constructability Challenges**
  - Remote operation in unshielded environments
  - Keeping buffer blocks dry
  - Handling large, heavy packages (up to 2 m OD × 5 m L)

# Salt D-Rep Design Considerations

- **Bedded or Domal Salt Constructability**
  - Opening stability
  - Salt backfill
- **Superior Heat Dissipation**
- **Nominal and Disturbed Performance**
  - Releases dominated by human intrusion
- **Natural Barrier**
  - Insignificant groundwater abundance and mobility (nominal)
  - Brine saturation (esp. human intrusion)
- **Engineered Barriers**
  - Backfill and seals
  - Robust containment during operations
  - Emplacement borehole behavior (e.g., heavy liners)

# Salt D-Rep Disposal Concept

- **Direct Disposal of Pour Canisters**
  - HLW glass stability in operational environment
- **Robust Overpacking of Other Waste Forms**
  - Carbon steel overpack (e.g., DSNF)
- **Just-in-Time Drift Construction**
  - Minimize handling of crushed salt
- **In-Drift Emplacement (axial or transverse)**
  - Relatively small, lightweight canisters (e.g., 6 MT HLW)
  - Immediate backfilling with crushed salt
- **Constructability Challenges**
  - Remote operation in unshielded environments

Used
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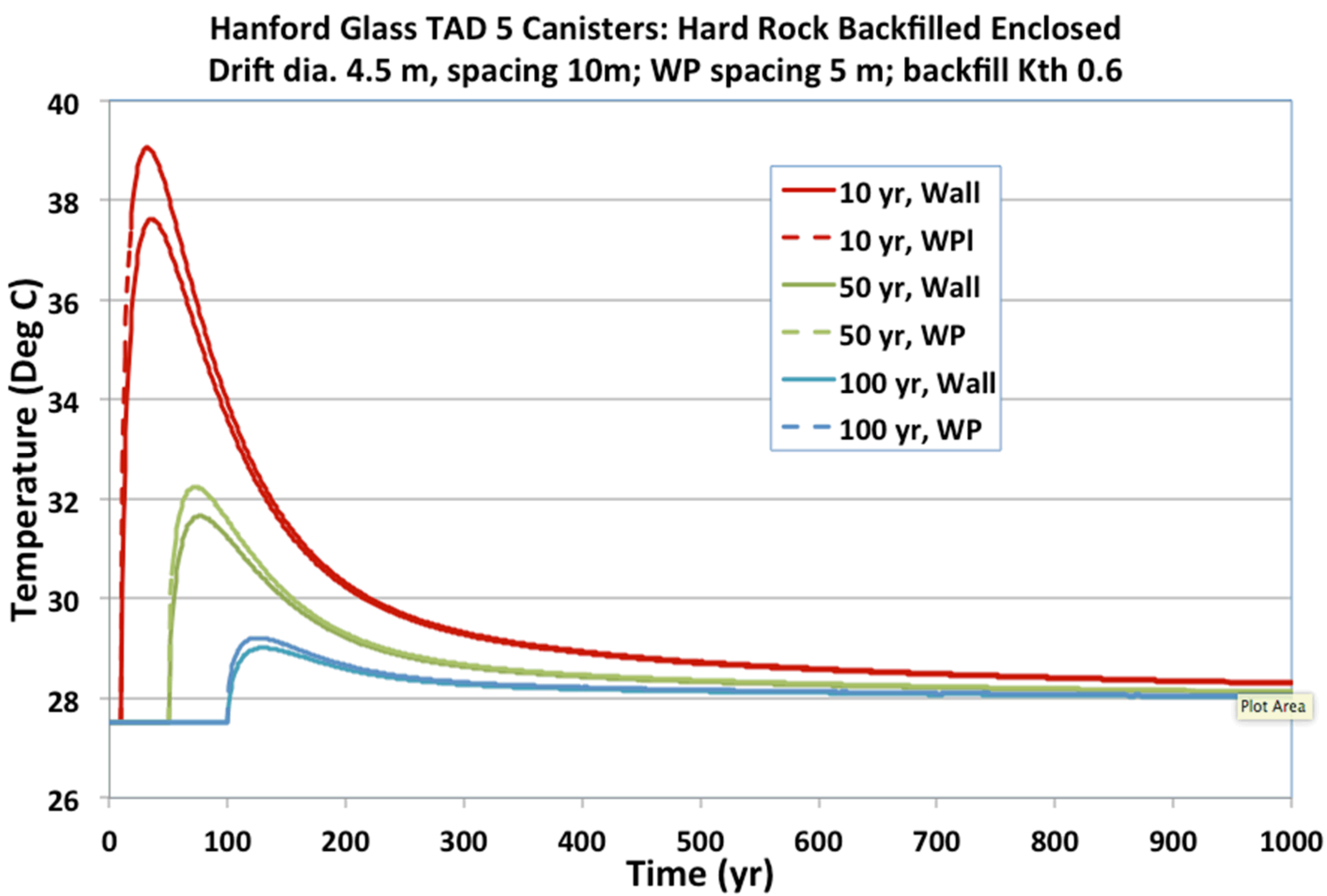
Disposition

# Preliminary Results Thermal Analysis



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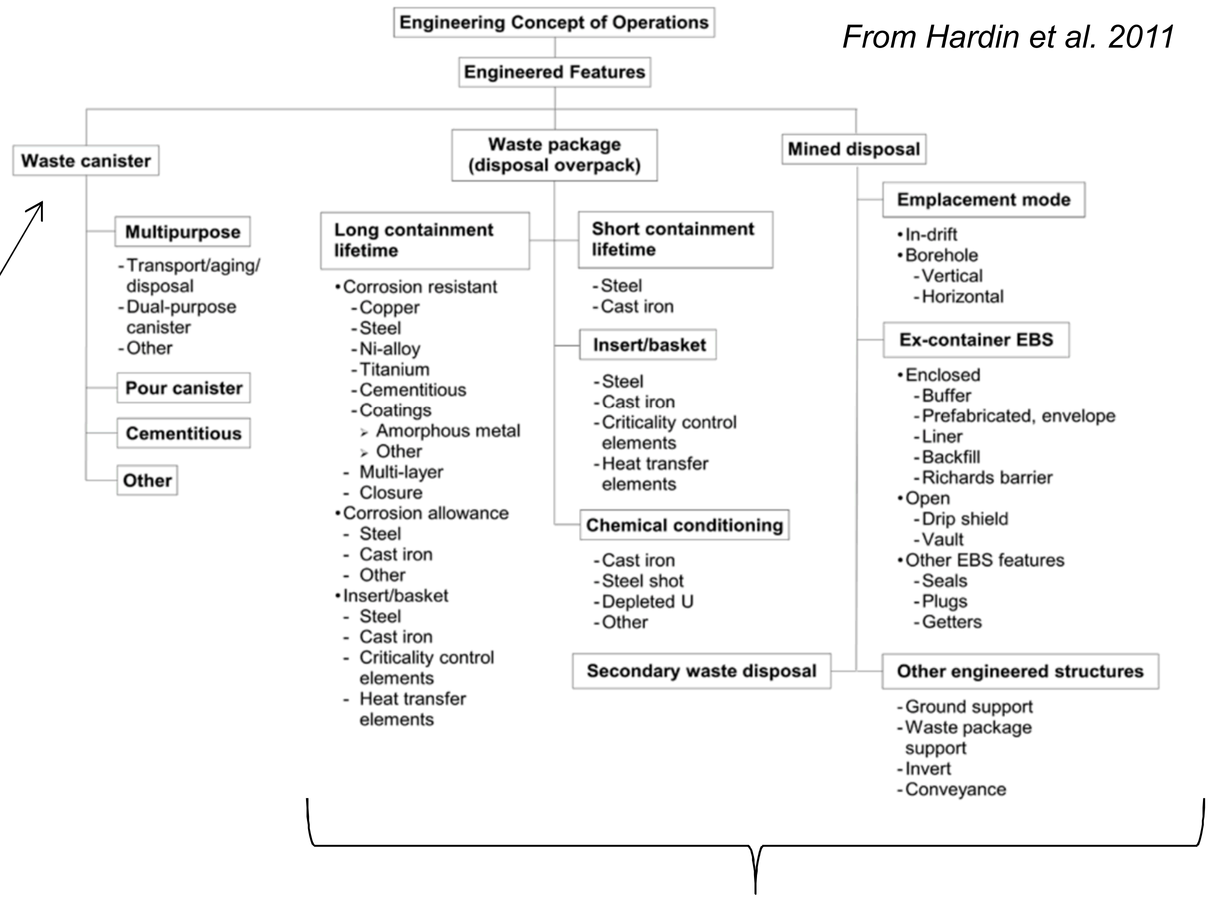


*Disposal Media*

# References

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*DOE (US Department of Energy) 2014. Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel. October, 2014.*

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