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Spent Fuel and Waste Science and Technology

DWR *Preliminary Design Concepts* Update

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SNL

SFWST Working Group Meeting
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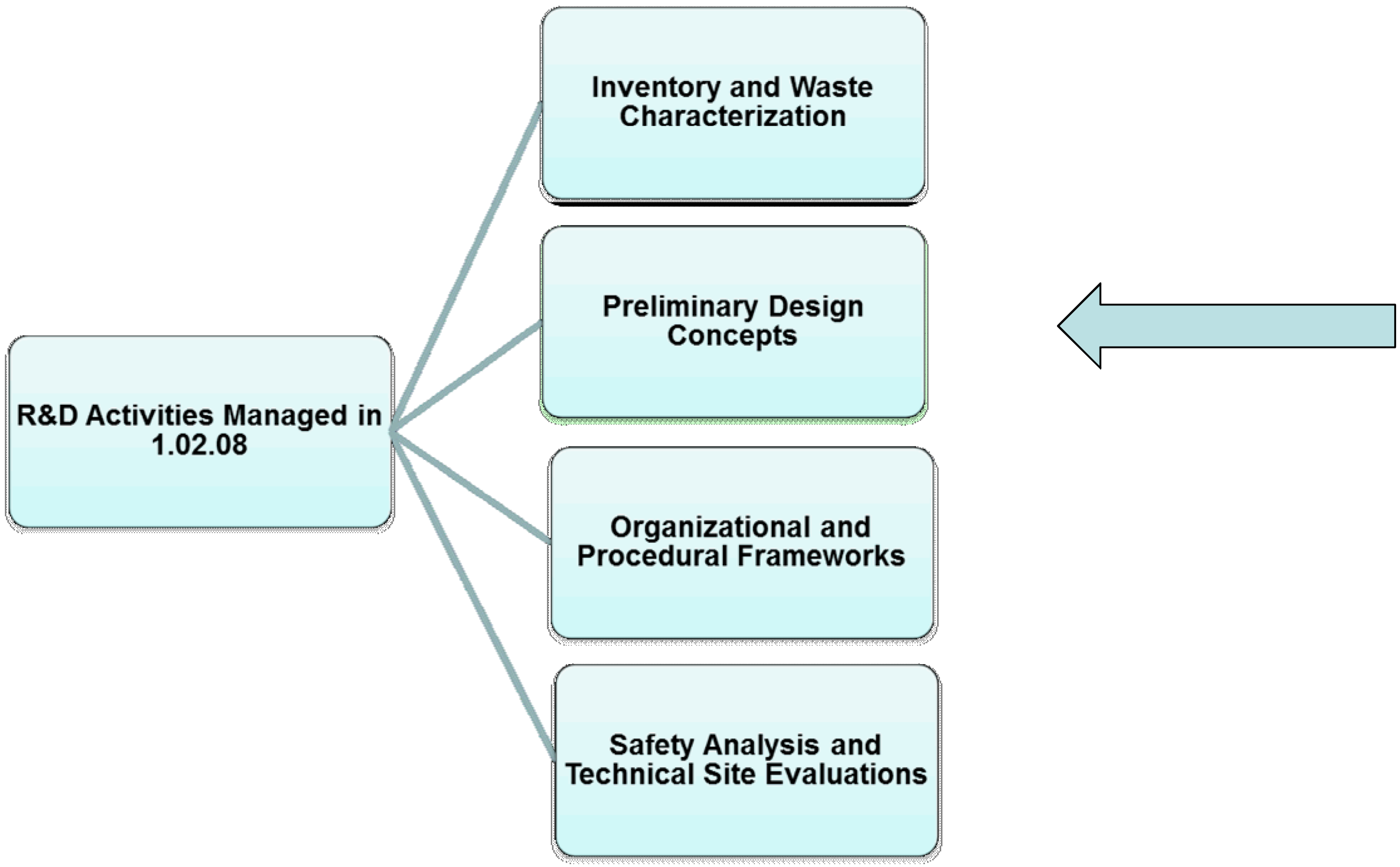
Structure of Technical Work Areas



Defense Waste Repository R&D *Preliminary Design Concepts* Overview 1/2

- **Objectives:**
  - Assess feasibility and applicability of Engineered Barrier Systems (EBS) concepts in select geologic media for the technical challenges specific to the inventory.
  - A particular emphasis will be placed on analyzing thermal conditions and their effect on the inventory's compatibility with EBS concepts/disposal media. (WP1)
  - Investigate and evaluate options for both disposal overpack and waste package design. (WP2)
  - Layout and emplacement. (WP3)

Defense Waste Repository R&D *Preliminary Design Concepts* Overview 2/2

- **Accomplishments**
  - Integration with *Inventory* and *Safety Analysis* WP's
  - Integration with *Argillite*, *Crystalline*, and *Salt* DR's
  - Select host media - Argillite (FY17), Crystalline, and Salt (FY16)
    - *Thermal Analysis*
    - *EBS Design*
    - *Waste Package and Overpack Design*
    - *Layout and Emplacement*

    based on a review of well-studied, published repository concepts (e.g. KBS-3 for crystalline) (applies to EBS Design, Waste Package and Overpack Design, and Layout and Emplacement)
  - FY16 M2 Milestone

Technical Feasibility of a Defense Repository 1/2

Safety:

- Operational Safety for workers and the public considering normal and off-normal events
- Post-closure Waste Isolation Performance
  - With reasonable assurance to meet regulatory performance objectives

Engineering Feasibility:

- Constructability
- Conveyance of waste packages to and within the underground
- Radiologic shielding
- Repository ventilation
- Control of workplace hazards
- Operational lifetime of facilities
- Closure

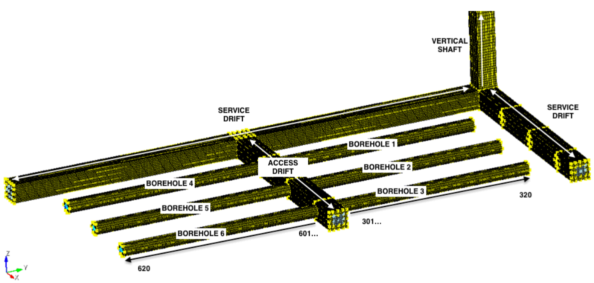
Technical Feasibility of a Defense Repository 2/2

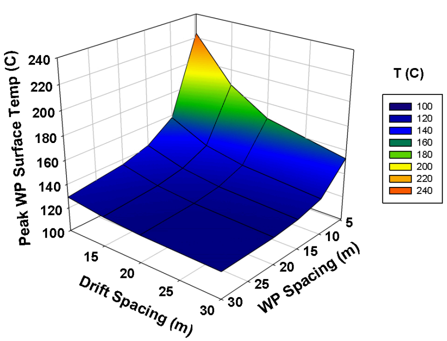
<u>Thermal Management:</u>

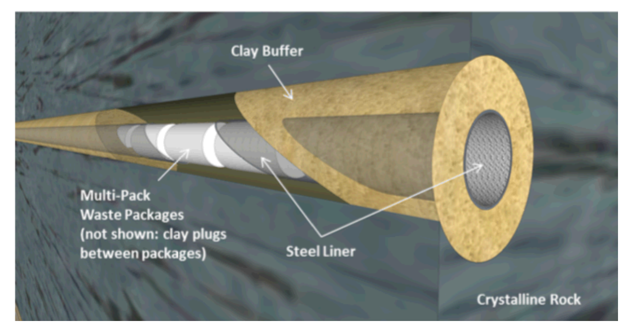
- Thermal limits
  - buffer and/or backfill (100º C for Argillite and Crystalline, 225º C Salt – host and backfill)
  - During operations and post-closure

<u>Post-closure Criticality Control (for DSNF):</u>

- Pre-canistered DSNF requires long-lived neutron absorbers at point of origin

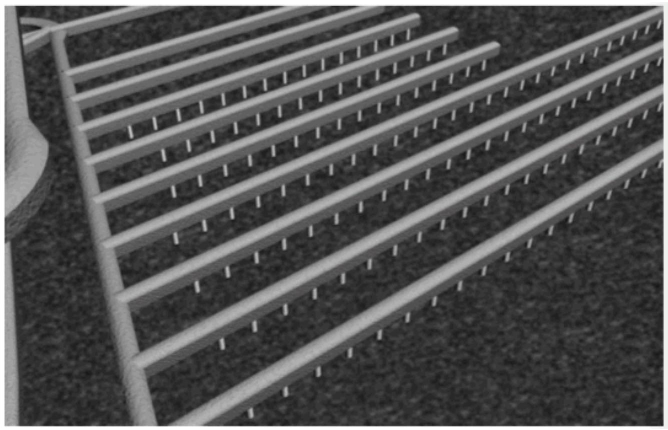




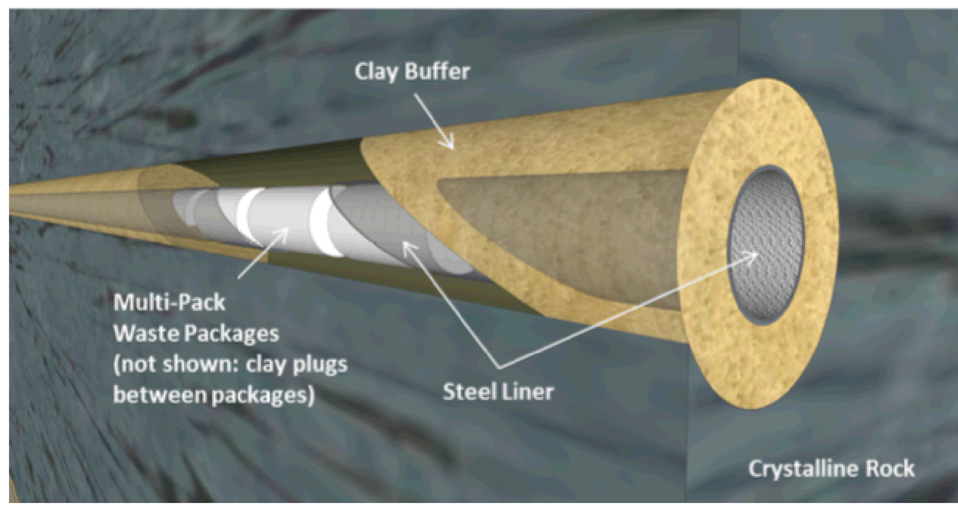


Crystalline Concept

Feature Dimension	DSNF Panel	HLW Panels
Emplacement opening	Short vertical boreholes (1 per package)	Long horizontal tunnels
Emplacement opening diameter	1.5 m (circular)	4.5 m (circular)
Emplacement opening depth or length	8 m deep	~100 m long
# of emplacement openings	4,000[A]	~267[B]
Approximate panel area by waste type	0.6 km^2	0.6 km^2
Access tunnel length	24 km access	~5 km
Access tunnel diameter	6 m (circular)	6 m (circular)
Access tunnel center-center spacing	24 m[C]	100 m minimum[D]
Package spacing center-center	6 m between emplacement boreholes	6.3 m (~1.5 m buffer between packages)
Waste package diameter	80 cm[E]	2.13 m[F]
Waste package length[G]	~4.8 m	~4.8 m
Waste package (overpack) material	Copper	Corrosion resistant[H]
Approximate weight	8.5 MT	50 MT
Buffer thickness[I]	35 cm	120 cm
Buffer material	Compacted, dehydrated swelling clay	
Backfill material	50:50 clay-sand	n/a
Analogous international concepts	KBS-3V (SKB 2011)	AECL concept for CSNF (Johnson et al. 1944)



http://www.posiva.fi/en/final_disposal/basics_of_the_final_disposal/backfill#.V9hTETXxVLc *(top and bottom)*



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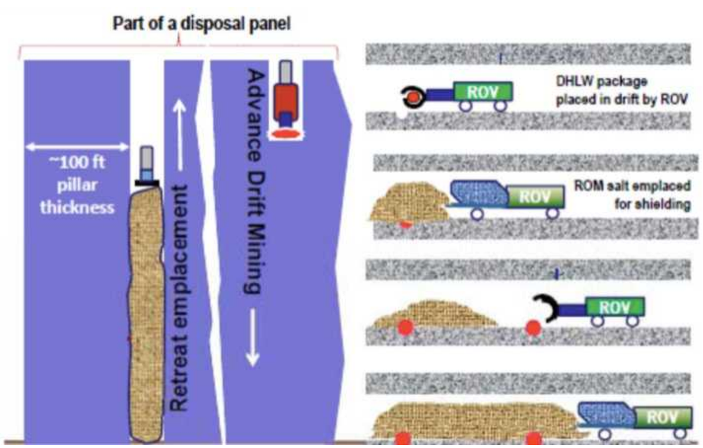
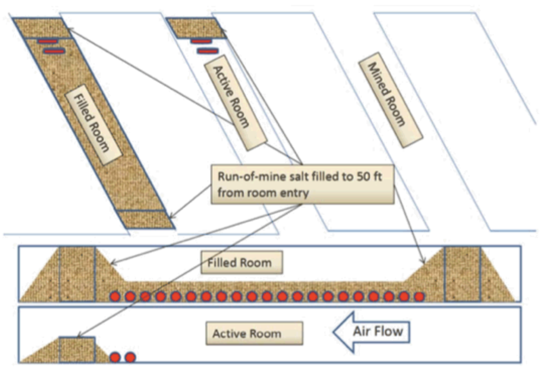
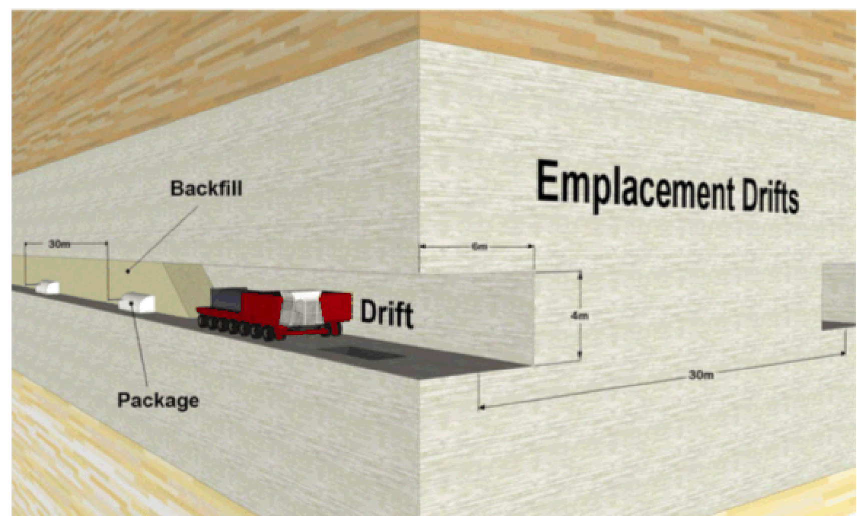
Salt Concept



Feature Dimension	DSNF	HLW
Emplacement drift dimensions	3 m high × 6 m wide	3 m high × 6 m wide
Emplacement drift length	~500 m	~500 m
Approximate # of canisters/waste packages per drift [A]	54	57 to 147
Emplacement drift center-center spacing [B]	20 m	20 m
Approximate total # of packages [C]	3,716	25,000
Panel emplacement area by waste type	0.7 km^2	1.7 to 4.4 km^2
Emplacement mode	In-tunnel transverse	In-tunnel transverse
Package spacing center-center	8.2 m [D]	~3 to 7.7 m [D]
Waste package diameter	80 cm [E]	61 cm [F]
Waste package length	~4.8 m [G]	~4.6 m [G]
Waste package (overpack) material	Steel	No overpack
Approximate total loaded package weight	15 MT	5.5 MT
Minimum transport weight with total shielding equivalent to 15 cm of lead	> 34 MT	> 32 MT
Backfill material	Crushed salt (porosity ~36%, a few w/w percent moisture)	
Analogous international concept	Horizontal in-tunnel disposal of POLLUX casks containing consolidated SNF (Filbert et al. 2010a)	



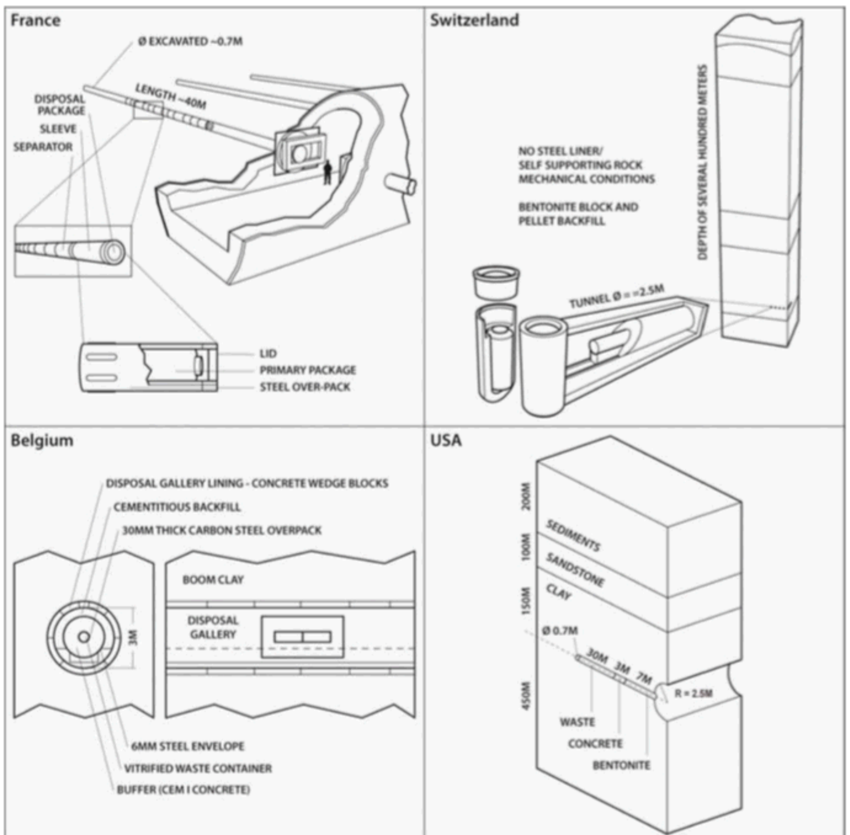
From Carter et al. 2012



From Hardin et al. 2015

Argillite Concept 1/3

- **As with the other host media, reliance and reference to technologically-mature, well-studied design concepts**



Argillite Concept 2/3

- **Argillite design is sensitive to by site specifics (e.g, claystone, vs. mudstone)**
  - Mechanical properties – impact constructability (e.g. tunnel liners, ground support)
  - Water content – impact on seal design esp. drift seals
  - Chemical composition - kaolinite, illite, smectite, organics, carbonates? – impact package/overpack design

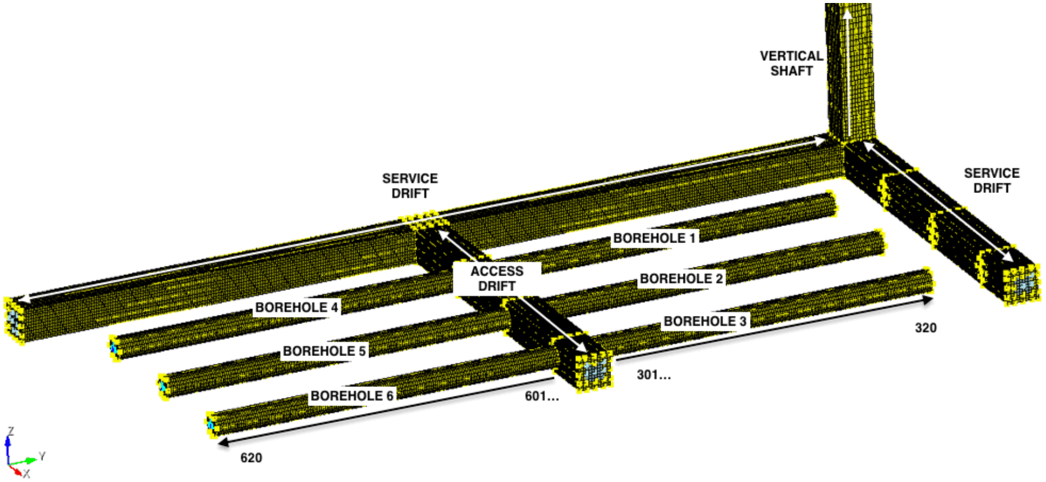
Shale Formation	Reference Location	Approximate Geologic Age (Ma)	Typical Thickness (m)	Top Burial Depth Present/Past (m)	Clay Content (wt. %)	Classification[1]	Mineralogy[2]	Carbonate Content (wt. %)	Hydraulic Conductivity (m/sec)	Compressive Strength[3] (MPa)	Organic Content (wt. %)	*In situ* Water Content (vol. %)
Europe:												
Opalinus Clay	Mont Terri, CH	180	160	250/1350	50 to 65	Claystone	Kaolinite, illite, illite/smectite	10 to 50	Est. 5×10^{-13} to 6×10^{-14}	12	0.5	4 to 6
Callovo-Oxfordian Argillite	Bure, France	155	130	400/na	45	Mudstone	Illite/smectite	20 to 30	Est. 3×10^{-14}	25	<3	5 to 8
Boom Clay	Mol, Belgium	30	100	220/na	55	Bedded mud	Smectite/illite	1 to 5	Est. 6×10^{-12}	2	1 to 5	22 to 27
North America (example formation included in OECD/NEA 1996 tabulation):												
Pierre Shale	Pierre, SD	70	400	150/na	50	Mudstone	Illite/smectite	0 to 50	10^{-13} to $10^{-14.6}$	7	0.5 to 13	~16 (variable)

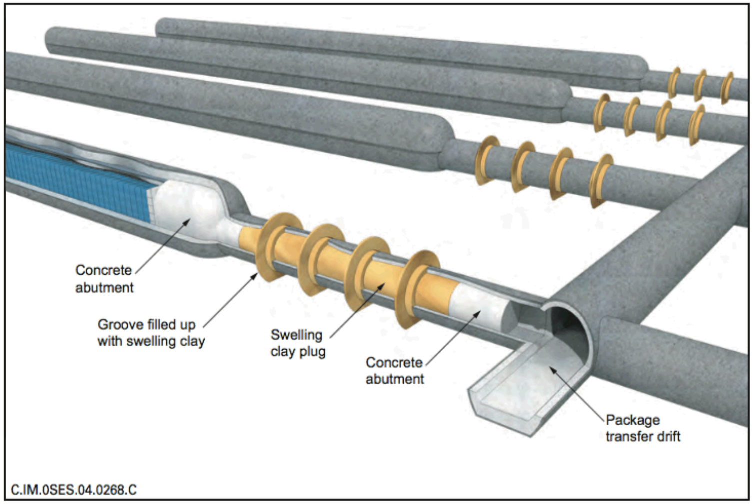
Sources: ANDRA 2005; Hansen and Vogt 1987; NAGRA 2002; NEA 2003; Neuzil 2000; Volckaert et al. 2005.

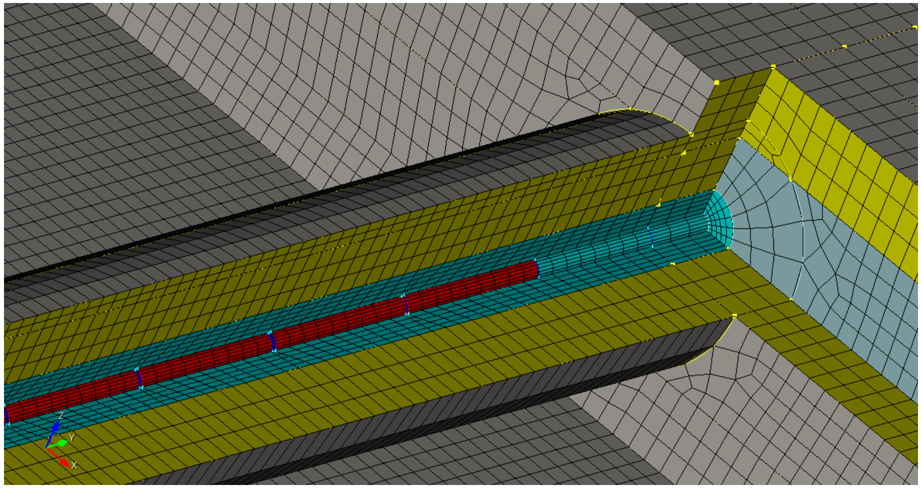
[1] Use clay-mud-claystone-mudstone-argillite classification from OECD/NEA 1996, p. 4.
[2] Predominant assemblage or combination: smectite, illite, kaolinite, chlorite, carbonate, etc.
[3] Unconfined, typical laboratory values for fresh samples.

NOTE: na = not applicable.

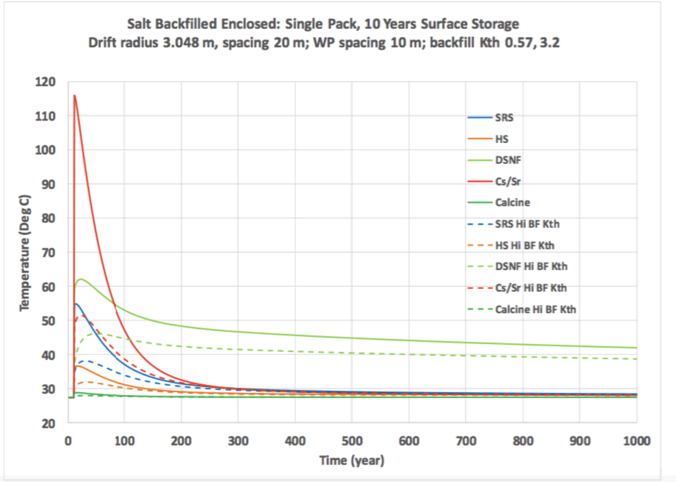
Argillite Concept 3/3

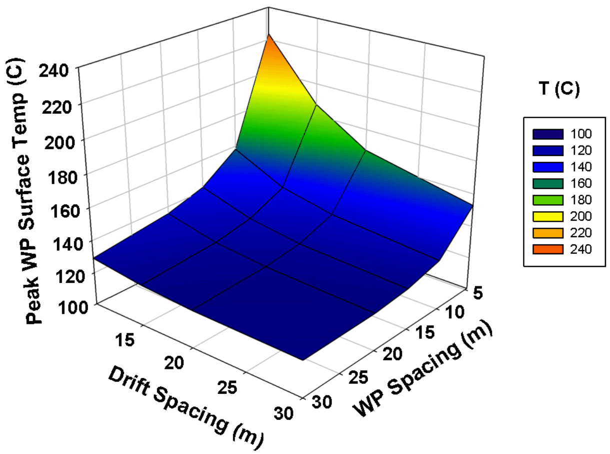




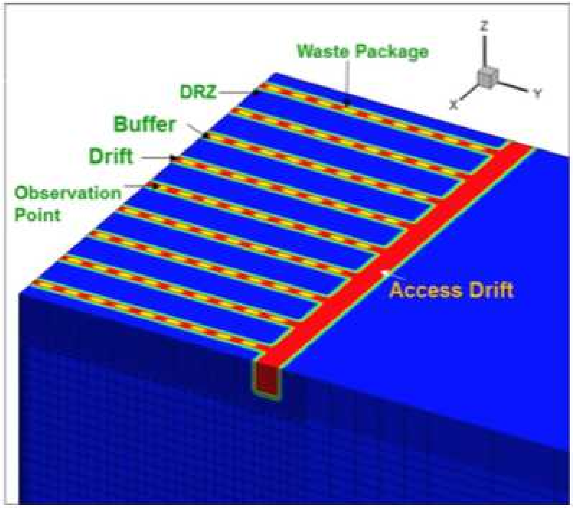


Thermal Analysis (all host media)





- **Semi-analytic model**
  - for surface and wall T
  - Sensitivity studies (e.g. waste package spacing)
- **TH model**
- **KOSINA Collaboration (Germany)**
  - Benchmarking Semi-Analytic with FLAC3D
  - TH analysis – FLAC and PFLOTRAN



References

Carter, J. T., Rodwell, P. O, Robinson, B., Kehrman, B. 2012. Costing Study for a Generic Salt Repository: Systems Engineering and Analysis in Support of a Policy Review of Comingling Decision and Related System Design Considerations, FCRD-UFD-2012-000113, Rev. 1., July 2012.

DOE (U.S. Department of Energy) 2008. Yucca Mountain Repository License Application Safety Analysis Report. DOE/RW-0573, Revision 1. U.S. Department of Energy, Washington, DC. (http://www.nrc.gov/waste/hlw-disposal/yucca-lic-app/yucca-lic-app-safety-report.html#1)

Hardin, E., L. Price, E. Kalinina, T. Hadgu, A. Ilgen, C. Bryan, J. Scaglione, K. Banerjee, J. Clarity, R. Jubin, V. Sobes, R. Howard, J. Carter, T. Severynse and F. Perry 2015. *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters*. FCRD- UFD-2015-000129 Rev. 0. U.S. Department of Energy, Office of Used Nuclear Fuel Disposition.

Matteo, E. N., E. L. Hardin, T. Hadgu, H. Park, C. Jové-Cólon, and M. Rigali 2016. *Status of Progress Made Toward Preliminary Design Concepts for the Inventory in Select Media for DOE-Managed HLW/SNF.* FCRD-UFD-2016-000081, U.S. Department of Energy, Office of Used Nuclear Fuel Disposition.

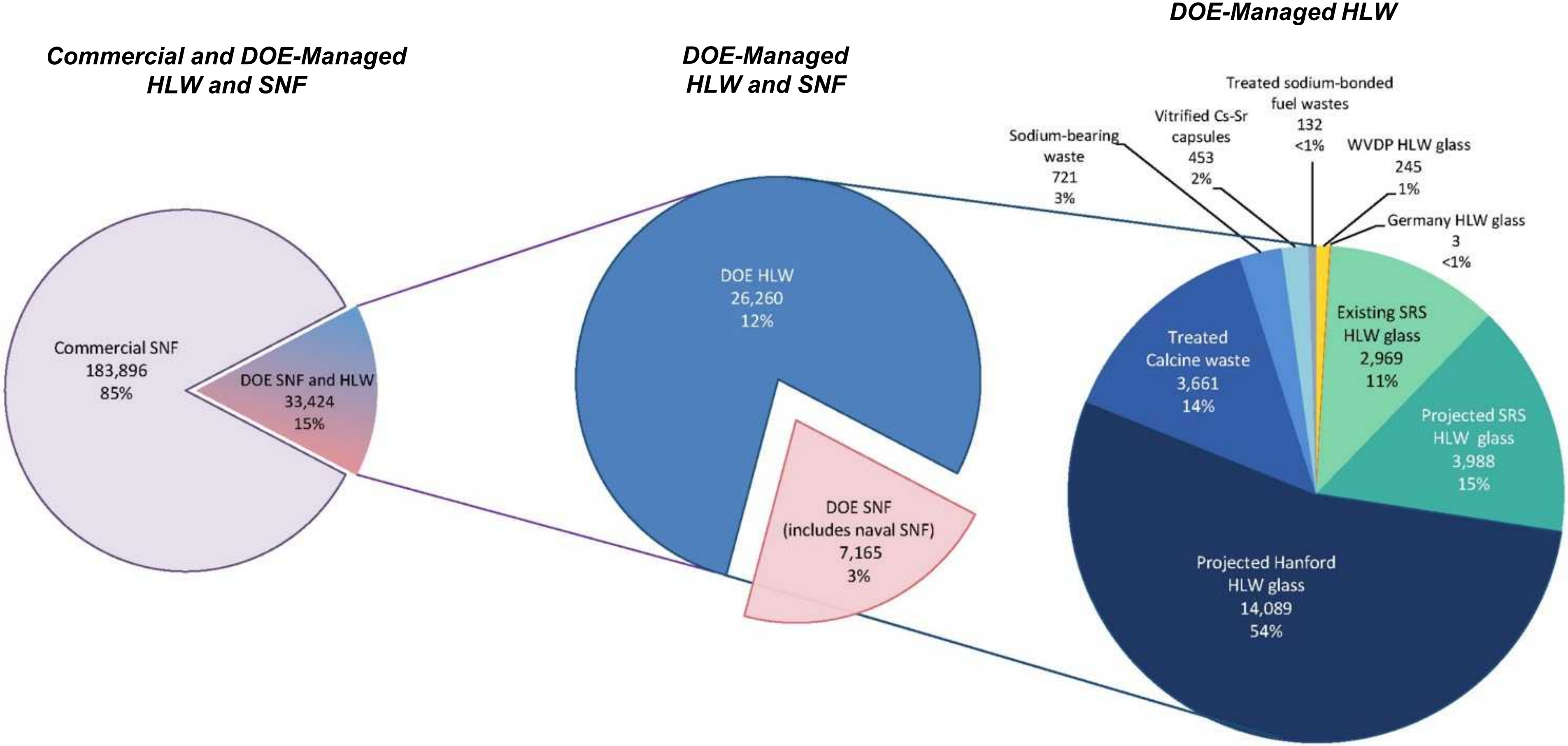
SNL (Sandia National Laboratories) 2014. Evaluation of Options for Permanent Geologic Disposal of Used Nuclear Fuel and High-Level Radioactive Waste Inventory in Support of a Comprehensive National Nuclear Fuel Cycle Strategy. FCRD-UFD-2013-000371. SAND2014-0187P; SAND2014-0189P. Revision 1. Albuquerque, New Mexico: Sandia National Laboratories.

Wilson, J. 2016. Decay Heat of Selected DOE Defense Waste Materials, FCRD-UFD-2016- 000636, SRNL-RP-2016-00249.

Back up Slides

Defense Waste Repository Inventory -- ~80% by volume is glass

Projected volumes in m^3



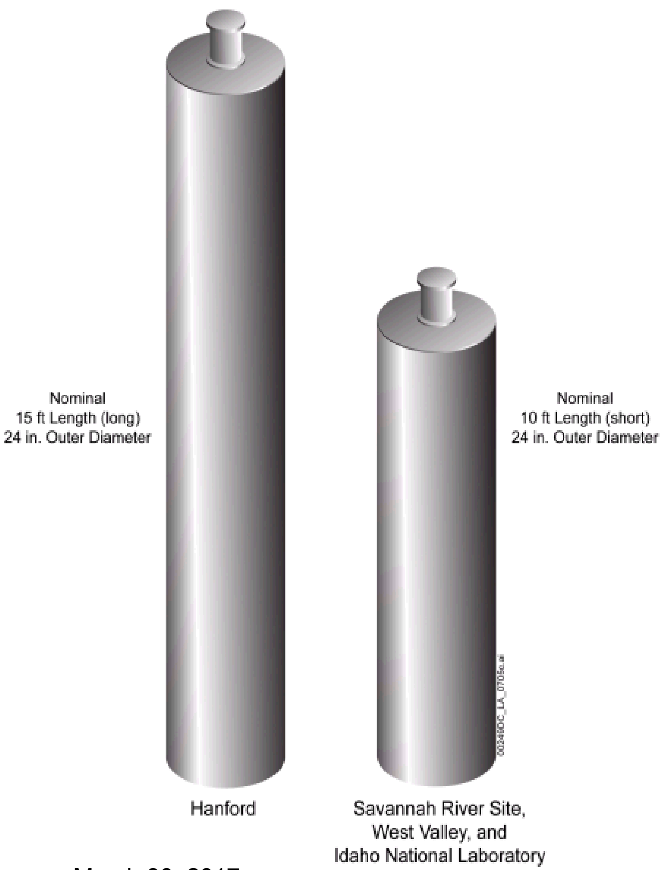
from SNL 2014

Waste Packages

HLW Glass

Diameter = 61cm (direct disposal)

Length = 3m or 4.57m



Defense Spent Nuclear Fuel

Diameter = 61cm (80cm including Steel overpack)

Length = 3.1m or 4.6m

(not used for Naval SNF)

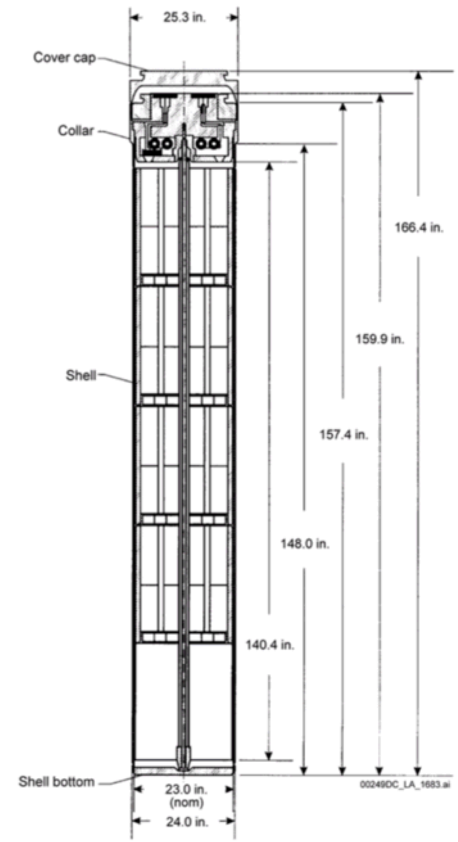
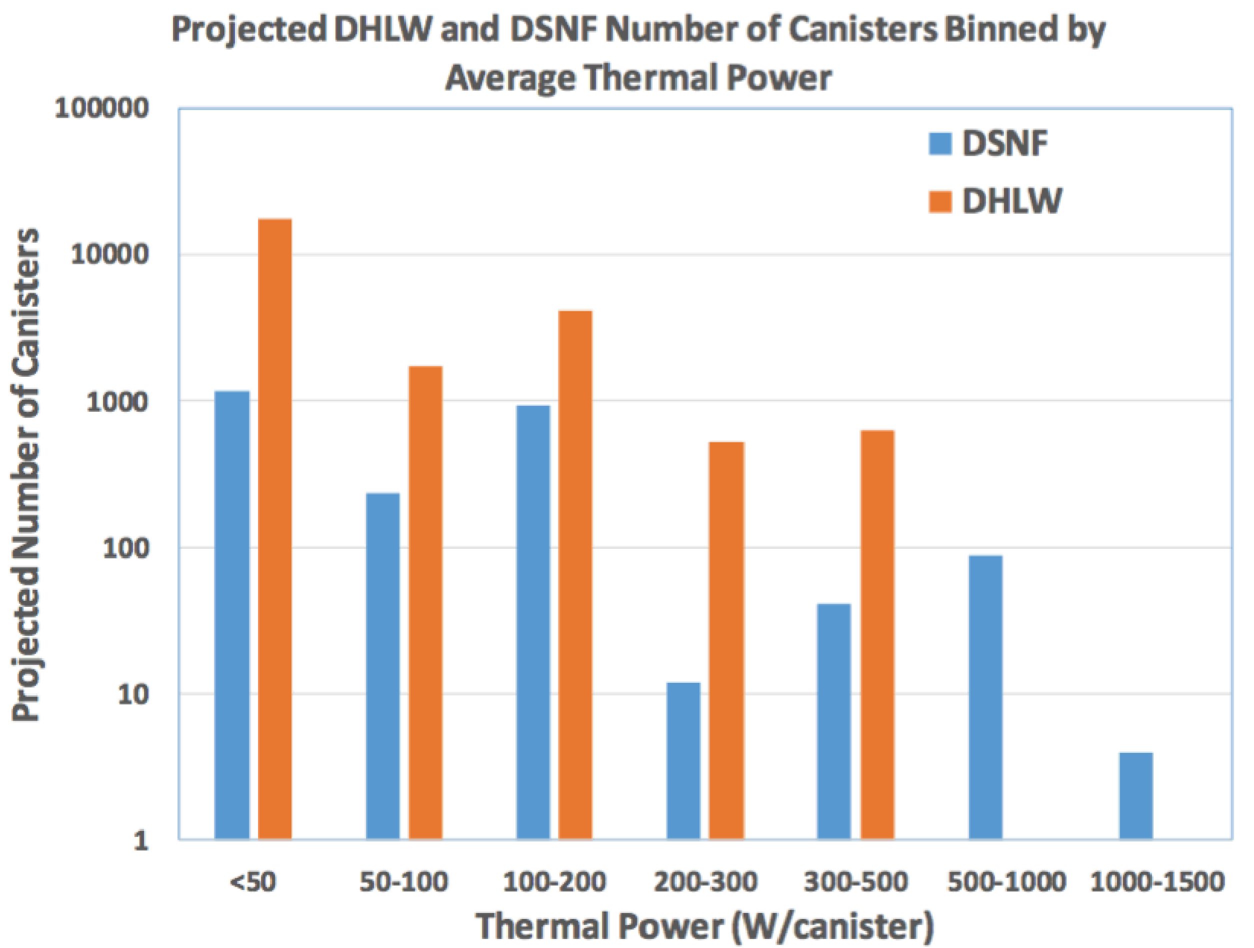


Figure 1.5.1-18. Multicanister Overpack

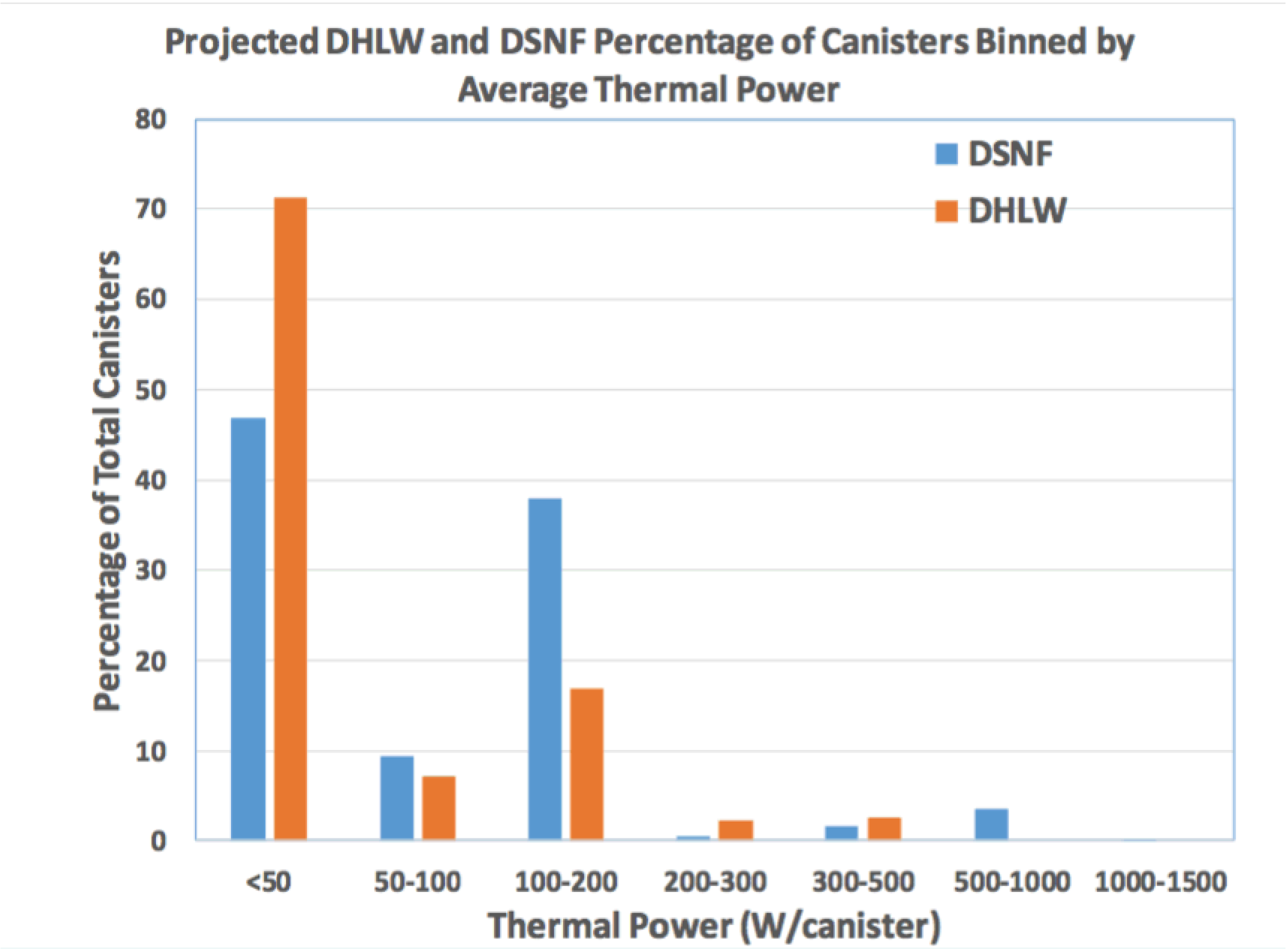
From DOE 2008 -- Yucca Mountain repository SAR (Figure 1.5.1-8 and Figure 1.5.1-18)

Distribution of Thermal Output per Canister (by # of canisters)



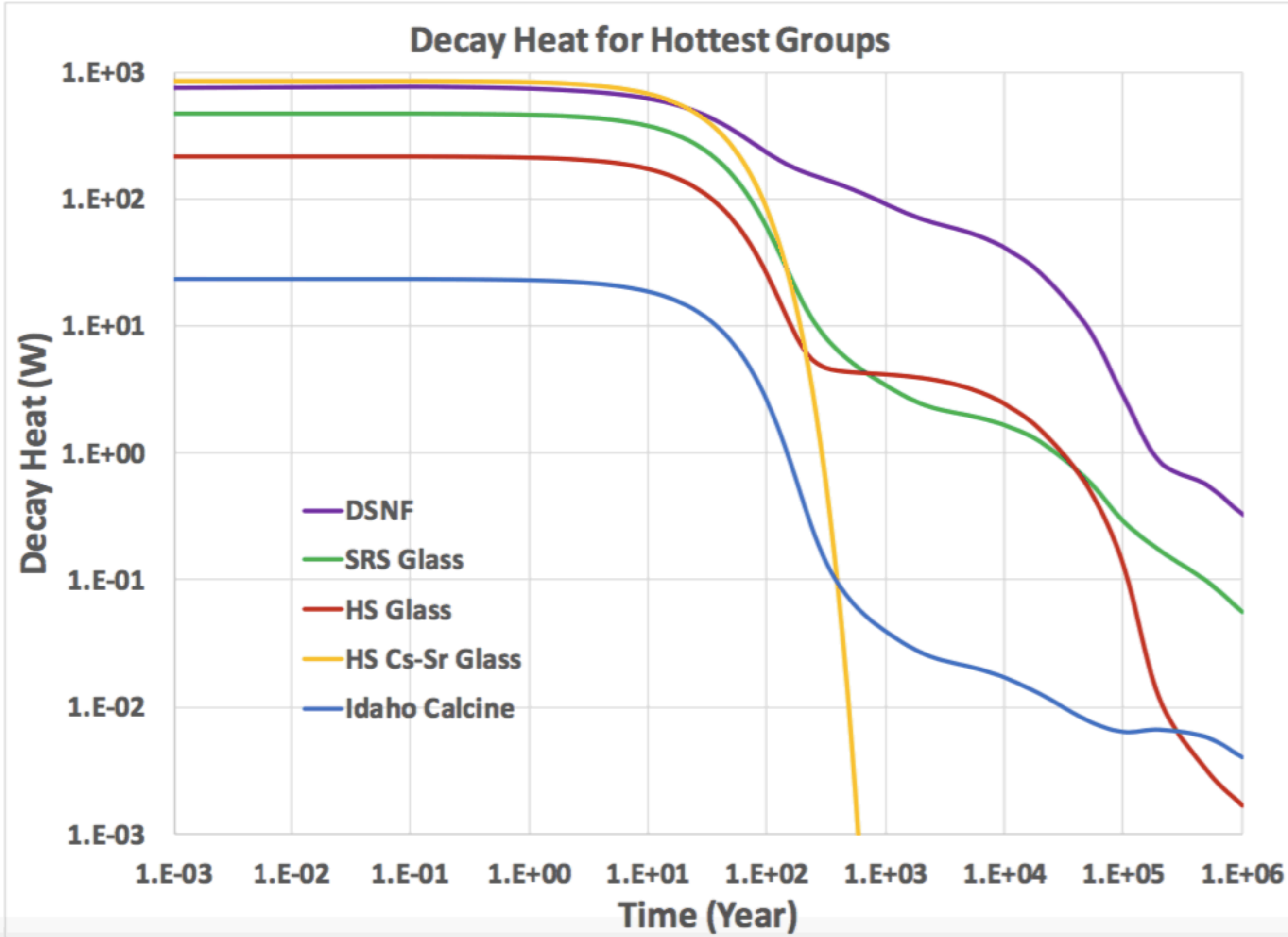
From Matteo et al. 2016

Distribution of Thermal Output per Canister (by % of each waste type)



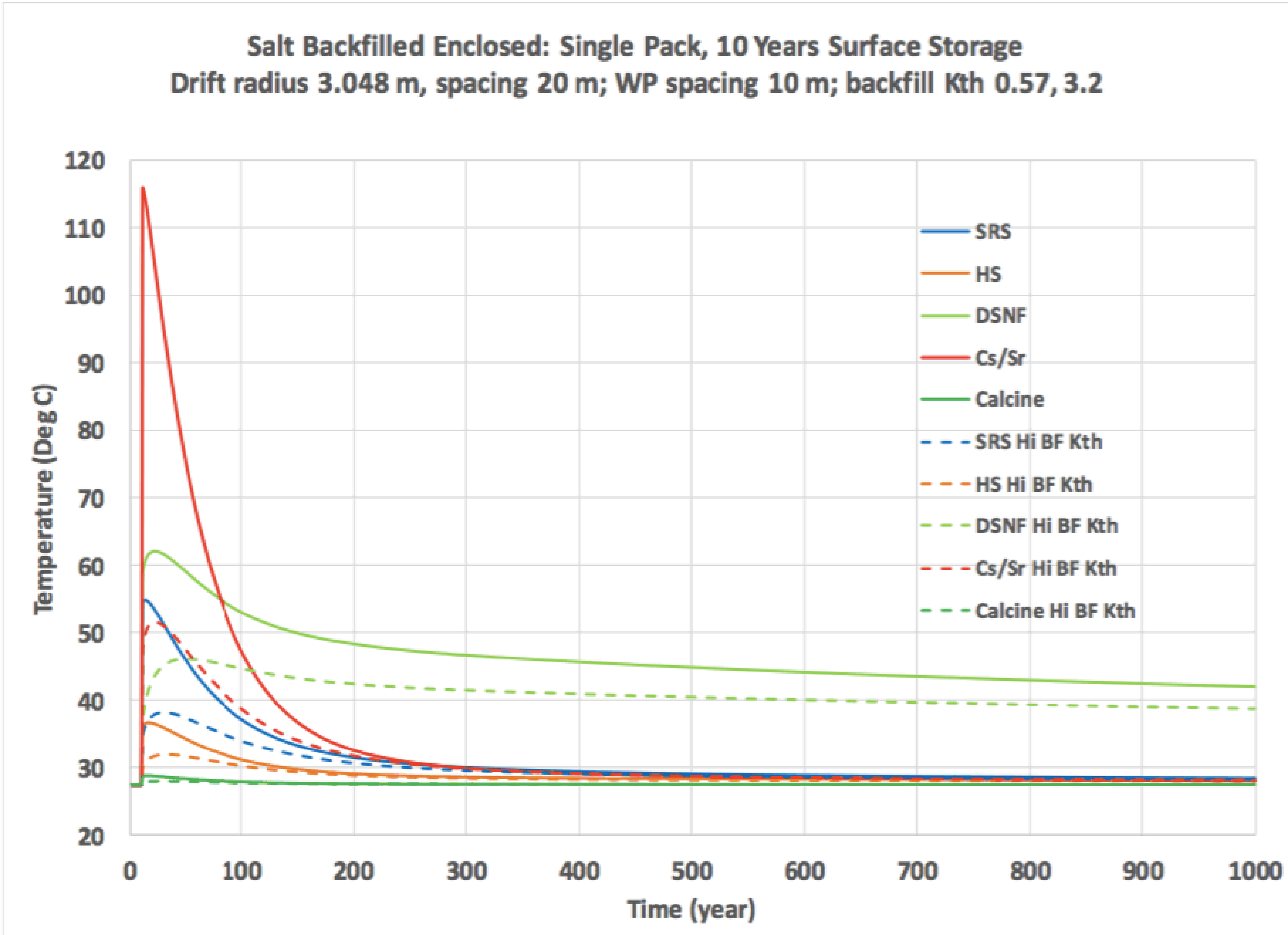
From Matteo et al. 2016

Decay Heat for Different Waste Types



From Wilson 2016

Temperature Histories at Waste Package Surface (10 years surface storage)



From Matteo et al. 2016

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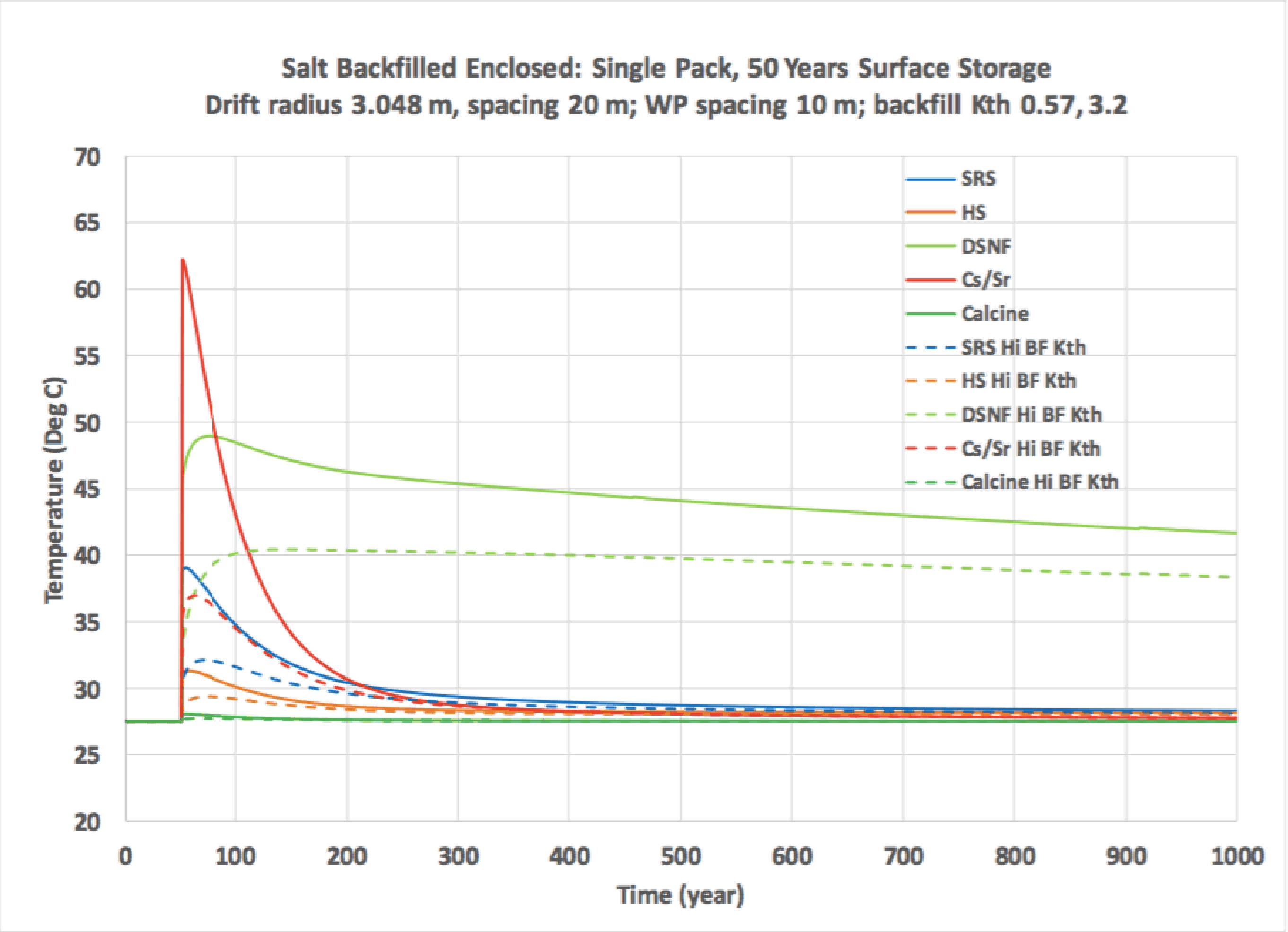
Temperature Histories at Waste Package Surface (50 years surface storage)



From Matteo et al. 2016