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Comparative Cost Analysis for Disposal of DPCs Relative to Repackaging

Abdelhalim Alsaed*, Ernest Hardin†

*Enviro Nuclear Services, 3595 S. Town Center Dr., Las Vegas, NV 89135, halimalsaed@environuclear.net
†Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, ehardin@sandia.gov

INTRODUCTION

There are currently more than 2,700 dual-purpose canisters (DPCs) containing spent nuclear fuel (SNF) across the United States. DPCs are welded canisters designed to meet dry storage requirements per 10 CFR 72 [1] and transportation requirements per 10 CFR 71 [2], with appropriate storage and transportation overpacks. Although 10 CFR 72.236(m) requires that "*To the extent practicable in the design of spent fuel storage casks, consideration should be given to compatibility with removal of the stored spent fuel from a reactor site, transportation, and ultimate disposition by the Department of Energy*," DPCs have been designed, licensed, and loaded without comprehensive disposal criteria, particularly not any that address postclosure criticality.

The License Application for Yucca Mountain [3] described a specialized disposal canister designed to meet storage, transportation, and disposal requirements. The performance specification for the Transportation, Aging and Disposal (TAD) canister [4] was informed by a specific geologic setting and performance objectives, to ensure that criticality events would be sufficiently unlikely that they could be excluded from performance assessment on the basis of low probability.

Repackaging DPCs into specialized disposal canisters would be financially and operationally costly with radiological, operational safety, and management risks. A disposition approach that would not involve repackaging or modifications to DPCs (future or already loaded) is the development of a disposal licensing strategy that addresses the risk (probability and consequence) from postclosure criticality events. A different approach would modify existing loaded DPCs (some or all of them), and change the loading or design of future DPCs, to decrease the probability of a criticality event in a repository below levels of concern.

This paper presents a comparative cost analysis between direct disposal of DPCs (i.e., emplacement of DPCs in disposal overpack), with or without modifications, and repackaging the SNF into disposal-ready canisters. This analysis investigates the cost to modify existing loaded DPCs, and the cost to modify the loading or design of future DPCs to facilitate direct disposal. It establishes the rough-order-of-magnitude (ROM) cost for repackaging SNF from DPCs into specialized disposal canisters. This analysis does not consider repository development and design.

Cost Analysis Scope

This comparative cost analysis considers cost of specialized disposal canisters, repackaging the SNF from DPCs, disposal of DPC hulls and baskets as low-level waste (LLW), disposal overpacks, treatment of existing DPCs, and modification of future DPCs. Treatment of existing DPCs is assumed to entail injectable fillers (cementitious material, molten metal, or glass), introduced in the DPCs through the vent/siphon ports. Modifications of future DPCs are assumed to entail: (1) use of disposal control rod assemblies (DCRAs) for pressurized water reaction (PWR) SNF and modified control blades for boiling water reactor (BWR) DPCs; (2) use of powder metallurgy borated stainless steel (ASTM A887-89 Grade A, UNS S30464) in lieu of (or in addition to) the aluminum-based neutron absorbers currently used in DPCs; or (3) establishment of criticality-oriented loading schema (congruent with existing thermal and shielding zone loading requirements) to minimize potential for postclosure criticality.

Some cost elements are taken from the Total System Life Cycle Cost (TSLCC) for Yucca Mountain [5] to allow for a comparative analysis. These costs are escalated to 2019 based on an assumed fixed annual inflation rate of 2%. Cost analyses are provided for the following four cases:

- Case 1 (Dispose of all DPCs with No Treatment or Modification) – Direct disposal of DPCs (in a disposal overpack) without treatment of existing DPCs or design/loading modifications to future DPCs. This case would likely be associated with a consequence-based consideration of postclosure criticality, disposal in a salt geology, or the use of engineered barriers that would preclude water from entering most DPCs.
- Case 2 (Fillers for Existing DPCs + Modified Loading for Future DPCs) – Direct disposal of DPCs, treating existing DPCs with fillers, and using criticality-oriented zone loading for DPCs loaded in the future.
- Case 3 (Fillers for Existing DPCs + BSS for Future DPCs) – Direct disposal of DPCs, treating existing DPCs with fillers, and design modifications for future DPCs to incorporate borated stainless steel plates.
- Case 4 (Fillers for Existing DPCs + DCRAs / Modified Blades for Future DPCs) – Direct disposal

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of DPCs, treating existing DPCs with fillers, and design modifications for future DPCs to incorporate DCRAs for PWR SNF and modified rods or control blades for BWR SNF.

Cost Analysis Bases and Assumptions

The following are key bases and assumptions for the comparative cost analysis [6]:

- This cost analysis is time-independent and does not consider length of storage or repository availability.
- The entire SNF inventory is assumed to be loaded in DPCs, except for the relatively small number of existing bare fuel casks (258 according to [7]).
- The cost of loading DPCs at utility sites is assumed to be a sunk cost and is not reflected in this comparative cost analysis.
- Where repackaging of fuel from DPCs to disposal canisters is analyzed, the disposal canister type is assumed to be equivalent to the Yucca Mountain TAD 21-PWR/44-BWR canister [4].
- The disposal drift length and associated engineered features (e.g., drip shields for the unsaturated hard rock disposal concept) are more correlated with thermal load than the number of packages; therefore, these costs are assumed to be non-discriminating for DPC disposal.
- A repackaging facility similar in size and throughput capacity to the Yucca Mountain Wet Handling Facility would be needed regardless of the disposal strategy for DPCs. This facility would accommodate packaging of fuel from bare fuel casks, of which there are currently 258, and other uncanistered SNF arriving at the repository in rail or truck casks (e.g., from decommissioning of fuel pools without use of dry storage).
- The repackaging facility is assumed to provide the infrastructure for introduction of fillers into existing DPCs to facilitate disposal. It is assumed that the reduction in operational costs associated with repackaging 920 DPCs, which is the basis for the TSLCC cost estimate [5], would offset the added cost associated with the addition of fillers to existing DPCs.
- Transportation cost considerations are not reflected in the comparative cost analysis, although the transportation cost for direct disposal of DPCs would be less than the transportation costs assumed in the TSLCC, which is based on transporting a larger number of lower capacity canisters.
- Fillers are assumed to be an acceptable treatment to facilitate disposal of DPCs. The cost of fillers is assumed to be $200k per DPC.
- The estimated cost of a DCRA that includes Zircaloy-clad rods containing a B_4C core, but without a spider assembly, is ~$50k; the total cost for seven DCRAs in a DPC (assumed to be sufficient to control postclosure criticality) would then be $350k. To simplify the cost analysis assumptions, the cost of modified control blades for a BWR DPC is also assumed to be $350k.
- The costs of borated stainless-steel plates for future DPCs with an average capacity of 34 PWR assemblies or 78 BWR assemblies are $174,000 and $354,000, respectively. The number of projected PWR and BWR DPCs is based on the projected PWR and BWR SNF inventory used in the TSLCC.

Cost Analysis Parameters and Values

The cost analysis parameters are summarized in TABLE I (adapted from [6]). Some parameters (e.g., numbers of existing DPCs) are current values that are certain to change with time. The total SNF inventory of 109,300 MTU is consistent with the TSLCC and reflects an estimate of SNF production from reactors with a 40-year lifetime without any extensions.

TABLE I. Comparative Cost Analysis Parameters

Parameter ($ values are rounded)	Value
SNF Total Inventory (MTU)	109,300
Total number of TADs	12,983
Total number of existing DPCs	2,700
Total number of future DPCs	5460
Total projected number of DPCs	8160
Cost per TAD canister	$937k
Total cost of TAD canisters	*$12.2b*
Cost of loading or unloading operations per canister (TAD or DPC).	$450k
Repackaging cost beyond what is assumed in the TSLCC	*$3.26b*
LLW volume for a DPC (m^3)	12.0
LLW disposal cost ($\$/m^3$)	$14.0k
Total LLW Disposal Cost	*$1.37b*
Cost of treatment of existing DPCs to facilitate disposal (per DPC)	$200k
Treatment cost for all existing DPCs	*$540m*
Cost of DCRAs/modified control blades	$350k
Cost of BSS for PWR DPC	$174k
Cost of BSS for BWR DPC	$354k
Cost of DPC modification	*Varies*
Cost per disposal overpack	$961k
Disposal overpacks cost reduction	*$4.64b*

RESULTS

The cost analysis results for the four scenarios are summarized in TABLE II and illustrated in Fig. 1. Negative values in the table represent savings compared to the full repackaging option.

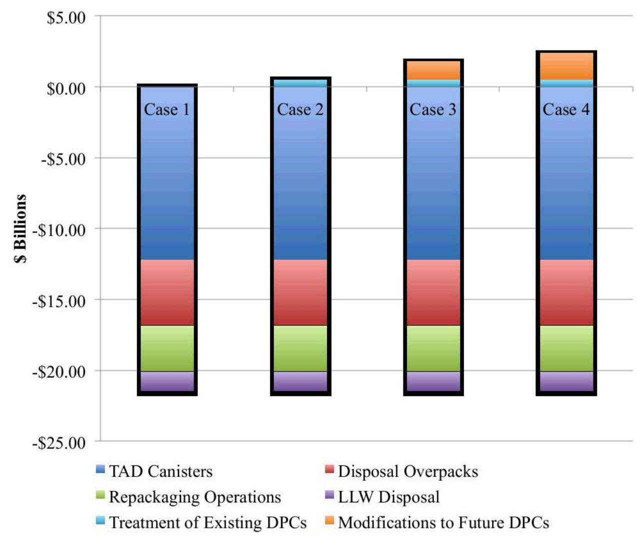

Fig. 1. Comparative Analysis Results.

TABLE II. Comparative Cost Analysis Results ($ billion)

Cost Element	Case 1	Case 2	Case 3	Case 4
TAD Canisters	-$12.2	-$12.2	-$12.2	-$12.2
Disposal Overpacks	-$4.64	-$4.64	-$4.64	-$4.64
Repackaging Operations	-$3.26	-$3.26	-$3.26	-$3.26
LLW Disposal	-$1.37	-$1.37	-$1.37	-$1.37
Treatment of Existing DPCs	$0.00	$0.54	$0.54	$0.54
Modifications to Future DPCs	$0.00[a]	$0.00[a]	$1.31	$1.91
Total Cost Avoidance	*-$21.4*	*-$20.9*	*-$19.6*	*-$19.0*

[a] The cost of modified loading is assumed to be minimal

The cost avoidance associated with direct disposal of DPCs is approximately $20 billion (escalated to 2019) for disposing of 109,300 MTU (quantity consistent with the TSLCC). If more SNF is produced and more DPCs are loaded, the cost avoidance would increase. Note that this cost avoidance does not take into consideration the sunk cost associated with loading of DPCs at utility sites. The significant contributors to cost avoidance are as follows:

- Elimination of TAD canister procurement accounts for $12.2 billion.
- Reduction in the number of disposal overpacks accounts for $4.64 billion.
- Elimination of repackaging operations accounts for $3.26 billion.
- Elimination of disposal of DPC hulls and baskets as LLW accounts for $1.37 billion.

The primary contributors to additional costs associated with direct disposal of DPCs are:

- Treatment of existing DPCs (i.e., fillers) accounts for $0.54 billion.
- Design modifications for future DPCs account for $1.31 billion if using BSS plates or $1.91 billion if using DCRAs and modified control blades.

The costs associated with potential treatment options for existing DPCs (represented for this analysis by injectable fillers and low-consequence screening) and design modifications to future DPCs, even if greater than estimated in this report, are far outweighed by the costs avoided by direct disposal of commercial SNF in DPCs.

Future cost analyses should evaluate the impact of the cost elements and parameters that were not considered in this evaluation. The following are some of those elements with potentially significant impact:

- Disposal Timing – Because DPCs generate more decay heat than smaller canisters, additional thermal aging may be needed prior to disposal. The cost of longer aging and delayed repository emplacement could reduce the avoided cost estimate.
- Transportation – Because DPCs generally have greater capacity than the assumed 21-PWR/44-BWR size, specialized disposal canisters, fewer shipments would be required for the same SNF inventory. Depending on where the standardized canisters are loaded (e.g., utility sites, centralized storage facility, repository facility) transportation considerations could increase the avoided cost estimate.
- Alternative Geology – The estimated avoided cost could be impacted if direct disposal of DPCs significantly impacts the emplacement drift design, emplacement method, overpack design, and other major engineering components relative to disposal-oriented canisters.
- DPC Cost Considerations – The current comparative cost analysis assumes that the cost of DPCs is a sunk cost; however, if DPC costs were factored into the analysis the results could change.
- Licensing Considerations – Licensing a geologic repository for disposal of DPCs could require more effort than licensing for repackaging in purpose-designed disposal canisters. Such effort could take the form of additional R&D and regulatory analysis, which could add years to the preparation of an

application. The costs of these activities could reduce the estimated avoided cost.

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