period are estimated by DOE to be 310 person-rem (Table D-9; DOE 2008a, Vol II., Appendix D, p. D-22). For a total LLW volume of 74,000 m3, this corresponds to 4.2 x 10^{-3} person-rem/m^3.

EPRI has independently calculated that there could be as many as 2,375 DPCs and other non-TAD canister-based systems loaded for storage of CSNF at reactor sites. If these DPCs are unloaded at Yucca Mountain for transfer of CSNF to TAD canisters, there will be corresponding increases in the volume of LLW requiring disposal and worker dose. Assuming a LLW volume of 10.6 m^3 for each DPC discarded, the corresponding volume of LLW would be 25,175 m^3, a 15,375 m^3 increase over the DPC volume assumed in the YMSEIS (DOE, 2008a). Using the 4.2 x 10^{-3} person-rem/m^3 unit dose calculated above, disposal of one DPC yields a unit dose of 0.045 person-rem. Likewise, disposal of a total of 2,375 DPCs would result in additional collective worker doses of 65 person-rem over the operations phase of the project. Disposal of the empty DPCs offsite along with other LLW would impose radiological risks to workers at commercial facilities. Relevant occupational doses associated with commercial low-level radioactive waste management are reported by NRC up through the year 1998 in NUREG-0713.[5] Worker doses of 0.1 rem/year appear representative for the most recent NRC data.

Table B - 9
Estimated Worker Dose Associated with Management of Empty DPCs (and Storage Only Canisters) as Low-Level Radioactive Waste

Scenario	Number of DPCs for Receipt at Yucca Mountain	Worker Dose for DPC Management as LLRW (person-rem)
YM SEIS (baseline)	307	14
YM SEIS High DPC Estimate	966	43
EPRI DPC Estimate	2375	110

The current DOE proposed approach does not call for unloading of DPCs at generator sites; however, it in conceivable that such a burden could be shifted to utilities and other ISFSI operators. Any LLW management activities resulting from the unloading of DPCs at the plant site would result in comparable (non-trivial) doses to workers at the generator end of the supply chain.

B.3.4 Radiological Impacts Associated with Additional Subsurface Construction Resulting from the Exclusive Use of Low Capacity TAD Canisters for CSNF

DOE's decision to use relatively low capacity 21P/44B TAD canisters will require the excavation of more emplacement drifts and associated access drifts than if higher capacity TADs and/or DPCs were accommodated in the proposed action. Accordingly, each additional,

[5] After 1998, all operating LLW facilities were located in NRC Agreement States and no longer reported annual dose numbers to the NRC.

unnecessary meter of drift that needs to be excavated and developed results in addition, unnecessary radiological risk to workers due to external and internal exposure from natural radioactivity and external exposure due to man-made radioactivity once emplacement of waste packages begins.

DOE envisions subsurface construction activities, including drift excavation and development, to occur over the initial 5 year construction phase and extending into the first 22 years of the operations phase of the repository.

Collective dose to workers is calculated on a unit (per meter) basis for drift excavation by summing collective doses over the construction phase and the first 22 years of the operations phase for involved subsurface craft workers and then dividing this dose by DOE's estimated total drift length (67,915 m) as discussed further in Appendix D. Involved subsurface collective dose for the construction period is estimated by DOE to be 33 person-rem (DOE 2008a,, Table 4-23, Vol. I, Ch. 4, pg. 4-66).

Total collective dose to involved workers during the operations phase is estimated by DOE to be 4,200 person-rem. The collective dose to involved subsurface craft workers is calculated by multiplying this total by the ratio of involved subsurface craft FTEs during operations (4339) to total involved staff FTEs during operations (23,399) (DOE, 2008b, non-rad H&S folder; filename: CAlcPkg_HS1_Attch1_JLS_09-04-07.xls). The resulting collective dose to involved subsurface craft workers during operations is 779 person-rem.

Based on the above calculations, EPRI estimates that the total dose to involved subsurface craft works would be 812 person-rem. The resulting dose on a per meter basis is then 0.012 person-rem/m or 0.067 person-rem/waste package (assuming 5.6 m per average waste package). As discussed in Appendix A.3, a total of 7400 CSNF waste packages would be disposed of using DOE's assumed 21P/44B TAD for CSNF. Under EPRI Case 1, a total of 5,080 larger capacity TADs would be disposed – 2,320 less than assumed in the YMSEIS. This results in a reduction in worker dose associated with subsurface operations of 155 person-rem. Under EPRI Case 2, a total of 5,929 larger capacity TAD waste packages would be disposed – a 2,471 reduction in waste packages. This results in a reduction of worker dose associated with subsurface operations of 166 person rem.

B.3.5 Radiological Impacts Associated with Drip Shield Installation

The YMSEIS assumes that the annual individual dose associated with installation of the drip shields is 9.75 mrem per year, with a staffing of 10 persons per year, resulting in a total dose of 97.5 person-mrem per year. The repository closure phase is assumed to last for 10 years, although it is not clear from the YMSEIS whether the drip shield installation operations will take place during the entire 10-year operations-closure phase. If drip shield installation takes five years, the total dose would be 487.5 person-mrem. If it takes ten years, the total dose for drip shield installation would be 975 person-mrem. (BSC 2007)

B.4 Radiological Impacts Associated with A One-Year Delay of CSNF Shipment to Yucca Mountain

While the YMSEIS and its associated calculational package did not calculate the additional radiological risk associated with additional construction at reactor site Independent Spent Fuel

Storage Installations (ISFSIs), documentation associated with DOE's No Action Alternative did evaluate these impacts. If additional ISFSI construction is required while there is already CSNF in dry storage, DOE's No Action Alternative assumed that there would be an additional 170 person-mrem per additional cask loaded (Jason 1999, Rollins 1998). In addition, as noted in Table A-4 above, ISFSI operation and maintenance was estimated to incur additional worker radiation exposure of:

- 120 person-mrem per year per site surveillance
- 1,500 person-mrem per year per site for annual maintenance

The YMSEIS assumes that there are 75 commercial reactor sites. If nuclear operating companies are discharging 2,200 MTU of CSNF from plants on an annual basis, this would require between 160 and 220 dry storage systems per year for additional on-site storage (assuming between 10 and 14 MTU per system). Thus, assuming that each reactor site would have an operational ISFSI by the 2020 time period, this results in the following industry wide impacts:

- 9 person-rem per year for ISFSI surveillance activities
- 112.5 person-rem per year for ISFSI annual maintenance
- 27 to 37 person-rem per year for additional ISFSI construction (170 person-mrem per cask loaded).

B.5 References

BSC 2007. Subsurface Worker Dose Assessment, Document ID 800-ooc-SS99-00600-000-00A, ENG.20070626.0020, June 2007.

DOE 2008a. Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F-S1, LSN #: DEN001593669.

DOE 2008b. Yucca Mountain Supplemental Environmental Impact Statement: Calculation Packages in Support of Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F-S1.

Jason 1999. Health and Safety Impacts during Controlled Long Term Storage of SNF and HLW in the U.S., Jason Technologies, April 1999, LSN #: DN2001094424.

Rollins 1998. Radiological Impacts for Scenario 1 at Commercial Nuclear Power Plants, Rollins, Tetra Tech NUS, October 1998, LSN #: DN2001483535

C
NON-RADIOLOGICAL WORKER IMPACTS

C.1 Non-Radiological Impacts at Reactor Sites

DOE considers non-radiological or industrial safety impacts to industry workers associated with CSNF storage at reactor sites and transport to Yucca Mountain, applying Bureau of Labor Statistics occupational hazard data from 2005 for total reportable cases (TRC) per 100 employees, lost workday cases (LWC) per 100 employees, and fatalities per 100,000 employees. Accordingly, EPRI utilized 2005 BLS data for consistency (BLS 2006a,b) Table C-1 provides data for relevant occupations.

Table C - 1
Occupational Injury and Fatality Rate Data for Relevant Occupational Categories in 2005 (BLS 2006a,b)

Category	NAICS code	TRC(per 100 FTE)	LWC (per 100 FTE)	Fatalities (per 100,000 FTE)
Construction	23	6.3	3.4	11.0
Warehousing and storage	493	8.2	5.4	17.6[a]
Truck transportation	483	6.1	3.9	17.6[a]
Rail transportation	482	6.0	4.5	17.6[a]
Utilities	22	4.6	2.4	3.6
Mining	21	3.6	2.2	25.6

[a]Fatalities for transportation and warehousing category, NAICS code 48-49

Fatality rates for specific high risk occupations that are relevant for Yucca Mountain construction and operation are also presented for illustration purposes in Table C-2..

Table C - 2
Selected Occupations with High Fatality Rates for 2005 (BLS 2006a,b)

	Fatalities (per 100,000)
Structural iron and steel workers	55.6
Driver/sales workers and truck drivers	29.1
Construction laborers	22.7

C.1.1 Non-Radiological Impacts Associated with Cask Loading and Handling

Loading and handling of canisters and cask systems represent is one of the key contributors to worker risk and is subject to substantial changes based on how and when DOE operates a repository. For the purposes of this report, EPRI estimates occupational impacts from

canister/cask loading and handling operations in two ways. The first approach assumes a representative output of canisters on an annual basis and yields calculated hazards based on estimated person-hours required for that activity. The second approach evaluates the differential impact of DOE's decision to adopt a standardized TAD canister for CSNF with a 21 PWR/44 BWR fuel element capacity.

For the first approach, EPRI assumes that loading and handling of one canister/cask system requires 400 person-hours (0.20 FTE). This assumption is based on estimates for loading, on site transport, and emplacement of a TN-32 horizontal cask system (Dominion, 2002). Applying Bureau of Labor Statistics data for warehousing and storage occupations, this translates into the following non-radiological impacts for each canister/cask loaded at reactor sites:

- TRC = 0.016
- LWC = 0.011
- Fatalities = 0.000035

For the second approach, EPRI adopted the approach used by DOE in its Final SEIS (DOE 2008a). According to the YMSEIS, the analysis of industrial safety impacts was based on an average loading duration of 2.3 days per rail cask for PWR SNF and 2.5 days per rail cask for BWR SNF. DOE's analysis assumed truck cask loading times of 1.3 days per cask for PWR SNF and 1.4 days per cask for BWR SNF. (DOE 2008a, Section G.1.3). A total of 1,347 worker-years would be spent on loading activities for involved workers. DOE also calculated non-involved worker impacts, assuming that the non-involved workforce would be 25% of the involved workforce.

According the YMSEIS, DOE based incidence and fatality rates on Bureau of Labor Statistics (BLS) data for 2005 (BLS 2006a,b), referencing the data for workers in the transportation and warehousing industries to estimate impacts associated with loading SNF casks. The following assumptions were used to calculate worker impacts associated with loading TAD canisters with CSNF:

- 8.2 TRC per 100 FTE for Involved Workers (warehousing and storage, 2005)
- 5.4 LWC per 100 FTE for Involved Workers (warehousing and storage, 2005)
- 17.6 Fatalities per 100,000 workers for Involved Workers (transportation and warehousing, 2005) (DOE 2008a, Table G-3)

Utilizing the above assumptions, DOE calculated industrial safety impacts to involved workers as summarized in Table C-3. Impacts included 110 total recordable cases (TRC); 73 lost workday cases (LWC) and 0.24 industrial fatalities for loading activities for CSNF, DOE SNF, DOE HLW, and Naval SNF. Assuming changes in the number of CSNF packages loaded, consistent with ERPI Case 1 and EPRI Case 2, EPRI recalculated the industrial safety impacts in order to quantify the increase in the impacts associated with DOE's selection of a 21P/44B TAD rather than a higher capacity TAD design similar in capacity to DPCs being loaded at reactor sites.

Table C - 3
Estimated Industrial Safety Impacts to Involved Workers During Loading Operations

Impact Type	Impact		
	DOE YMSEIS	EPRI Case 1	EPRI Case 2
Total recordable cases	110	91	79
Lost workday cases	73	60	52
Industrial Fatalities	0.24	0.20	0.17

As shown in Table C-3, DOE's selection of a 21P/44B TAD rather than a higher capacity TAD design similar in capacity to DPCs being loaded at reactor sites today results in the following increased health and safety impacts to involved workers:

- 19 TRC
- 13 LWC
- 0.04 industrial fatalities

DOE's selection of a 21P/44B TAD rather than a higher capacity TAD and its assumption that seven commercial nuclear power plant sites would ship CSNF to Yucca Mountain using truck casks rather than DPCs or large capacity TADs results in 4,217 additional packages being loaded at reactor sites. This results in the following increased health and safety impacts to involved workers:

- 31 TRC
- 21 LWC
- 0.07 industrial fatalities

C.1.2 Non-Radiological Impacts Associated with ISFSI Operation and Maintenance

As part of its occupational health and safety calculations, DOE in its YMSEIS used the following assumptions for ISFSI operation and maintenance.

- Total inspection/security surveillance: 30 person-hours per year (0.015 FTE)
- Total maintenance: 30 person-hours per year (0.015 FTE)
- Total for ISFSI operational and maintenance: 60 person-hours per year (0.030 FTE)

Using the Bureau of Labor Statistics injury and fatality rates for the utility occupational category (NAICS code 22) yields the following projected annual impacts at each ISFSI site for surveillance/inspection:

- TRC 0.00069
- LWC 0.00036
- Fatalities 5.4×10^{-7}

Likewise, annual impacts at each ISFSI for routine maintenance are calcualated to be:

- TRC 0.00069
- LWC 0.00036
- Fatalities 5.4×10^{-7}

C.1.3 Non-Radiological Impacts Associated with ISFSI Expansion and Construction

Using BLS injury and fatality data for the construction industry and assuming that the estimated time associated with construction of one horizontal storage module is 1500 person-hrs (0.75 FTE) (Rollins, 1998), EPRI estimates the following non-radiological impacts associated with ISFSI expansion and construction of additional storage modules:

- TRC 0.047
- LWC 0.026
- Fatalities 0.000083

Assuming that the estimated time asociated with construction of an additional ISFSI storage pad is 7090 person-hrs (3.5 FTE) (Dominion, 2002), EPRI estimates the following non-radiological impacts associated with ISFSI expansion and construction of one additional ISFSI storage pad:

- TRC 22
- LWC 12
- Fatalities 0.00039

C.2 Non-Radiological Impacts to Workers During Transport

The YMSEIS idenfies the probablity of a rail transport accident to be 1.15 × 10-8 fatality/railcar-km (DIRS 178016-DOT 2005, all). For shipments involving 3 spent nuclear fuel casks (8 railcars total), the fatality rate was estimated to be9.20 × 10-8 accidents/train-km.

In the YMSEIS, the non-radiological fatality rate associated with rail accidents was estimated to be 1.15×10^{-8} fatality/railcar-km. For shipments involving three CSNF casks (8 railcars total), the fatality rate was estimated to be 9.20×10^{-8} accidents/train-km. Thus, a reduction in the number of cask shipments that results in a reduction in the number of train shipments would reduce the risk of transportation accidents and fatalities. (Source: DOE 2008b, p. 53)

The YMSIES identifes the probablity of truck transport accidents. Truck accident and fatality rates are state specific; however the average accident rates for trucks are:

- 5.34E-07 accidents per truck km

- 55E-08 fatalities per truck km

(Source: DOE 2008b, Attachment 8A Database)

C.3 Non-Radiological Impacts to Workers at Yucca Mountain

The YMSEIS estimated non-radiological health and safety impacts to workers at Yucca Mountain from industrial hazards using the Computerized Accident/Incident Reporting System (CAIRS) database. CAIRS is a DOE database that collects reports of injuries, illnesses, and accidents that occur at DOE sites. It records TRC and "days away, restricted or on job transfers", which is equivalent to the BLS LWC category. Table C-4 presents the non-radiological health and safety statistics used in the SEIS to calculate impacts to involved workers.

Table C - 4
DOE Occupational Injury and Fatality Data for Construction and Operations Periods from CAIRS Database

Project period	TRC	LWC	Fatalities	Source
Construction	2.0	0.86	0.55	DOE 2008a, Table 4-16), Section 4.1.7.1
Operations	1.4	0.58	0.55	DOE 2008a, Table 4-20, Section 4.1.7.1.2

The YMSEIS calculated the impacts to involved workers during construction, operation, monitoring and closure of the repository, as summarized in Table C-5. While the calculational packages that support the YMSEIS does contain a breakout of worker hours for each of the operational periods identified in Table C-5, EPRI was not able to identify the specific worker hours associated with handling of the TAD packages for receipt, waste package closure, aging and emplacement. Therefore, EPRI was not able to identify the increase in worker hours associated with DOE's decision to utilize a 21P/44B TAD package and rather and higher capacity TAD packages as described by EPRI Case 1. Similarly, EPRI was not able to identify the increase in worker hours associated with DOE's decision to utilize a 21P/44B TAD design and to ship CSNF using truck casks from seven commercial nuclear power plant sites.

EPRI has not quantified the additional industrial hazards to workers associated with the receipt and handling the 9,456 CSNF casks assumed in the DOE YMSEIS, rather than a total of 7,548 casks under EPRI Case 1 – a 20% reduction in the number of packages handled and emplaced. Similar, under EPRI Case 2, industrial hazards associated with handling 5,239 casks under EPRI Case 2 – more than a 40% reduction in packages handled – would be lower than the impacts associated with handling 9,456 CSNF casks as assumed by DOE.

Table C - 5
Impacts to Involved Workers During Construction, Operations, Monitoring and Closure Periods for a Yucca Mountain Repository

Impact Category/Operations Period	Impact
Construction	
▪ TRC	120
▪ LWD	50
▪ Fatalities	0.032
Operations – Surface Construction	
▪ TRC	53
▪ LWC	23
▪ Fatalities	0.015
Operations – Subsurface Construction	
▪ TRC	87
▪ LWC	37
▪ Fatalities	0.024
Operations – Emplacement Operations	
▪ TRC	160
▪ LWC	67
▪ Fatalities	0.064
Operations – Maintenance	
▪ TRC	68
▪ LWD	28
▪ Fatalities	0.027
Monitoring	
▪ TRC	320
▪ LWC	130
▪ Fatalities	0.31
Closure	
▪ TRC	320
▪ LWC	150
▪ Fatalities	0.15
Source: DOE 2008b, H&Snonrad File, Attachment 1	

C.3.1 Non-Radiological Impacts Associated with Receipt, Handling, and Aging of CSNF

Not estimated as a separate category. Refer to Section C.3 above.

C.3.2 Non-Radiological Impacts Associated with Unloading Additional Dual-Purpose Canisters

Not estimated as a separate category. Refer to Section C.3 above.

C.3.3 Non-Radiological Impacts Associated with Management of Empty DPCs as Low-Level Radioactive Waste

In terms of non-radiological hazards, the handling of empty DPCs will also incur non-trivial risks to workers due to the routine hazards of handling heavy materials. Each empty DPC can weigh on the order of 36,000 lbs to 58,000 lbs. For Yucca Mountain work, DOE uses occupational hazard figures derived from its own experience as documented agency's CAIRS database. For the operational phase, these occupation risk numbers are: 1.4 TRC per 100 FTEs, 0.58 LWC per 100 FTEs, and 0.55 fatalities per 100,000 FTEs. Disposal of the empty DPCs offsite would, likewise, impose non-radiological risks to workers at commercial facilities. For these workers, it would be appropriate to apply BLS data (from Section B.1):

- 8.2 total recordable cases (TRC) per 100 FTE for Involved Workers (warehousing and storage, 2005)
- 5.4 lost workday cases (LWC) per 100 FTE for Involved Workers (warehousing and storage, 2005)
- 17.6 Fatalities per 100,000 workers for Involved Workers (transportation and warehousing, 2005) (DOE 2008a, Table G-3)

The current DOE proposed approach does not call for unloading of DPCs at generator sites; however, it in conceivable that such a burden could be shifted to utilities and other ISFSI operators. Any LLRW management activities resulting from the unloading of DPCs at the plant site would present occupational risk to those involved workers.

C.3.4 Non-Radiological Impacts Associated with Additional Subsurface Construction Resulting from the Exclusive Use of Low Capacity TAD Canisters for CSNF

DOE's decision to use the 21P/44B TAD canisters rather than higher capacity TADs will require the excavation of more emplacement drifts and associated access drifts than if higher capacity TADs and/or DPCs were accommodated in the proposed action. Accordingly, each additional, unnecessary meter of drift that needs to be excavated and developed results in addition, unnecessary radiological risk to workers due to external and internal exposure from natural radioactivity and external exposure due to man-made radioactivity once emplacement of waste packages begins.

DOE proposes subsurface construction activities, including drift excavation and development, occurring over the initial 5 year construction phase and extending into the first 22 years of the operations phase of the repository.

EPRI calculated the non-radiological occupational risks associated with drift excavation on a unit (per meter) basis by summing the respective occupational health and safety categories (TRC, LWC, and fatalities) over the construction phase and operations phase for involved subsurface craft workers and then dividing by DOE's estimated total drift length (67,915 m). Occupational health and safety numbers for subsurface construction during the construction phase are calculated by applying the ratio of the subsurface craft FTEs (336) to the total FTEs (5,886) for the period (DOE 2008b, non-rad H&S folder; filename: CAlcPkg_HS1_Attch1_JLS_09-04-07.xls). As shown in Table C-6, EPRI calculated that the fraction of FTE associated with subsurface craft workers is 0.057. Table C-7 summarizes the worker health and safety impacts during the construction phase from the YMSEIS – with 117.2 TRC, 50.2 LWC, and 0.032 fatalities. Using the subsurface craft worker fraction calculated in Table C-6, EPRI estimated the worker impacts during the construction phase for subsurface workers – 6.69 TRC, 2.86 LWC, and 0.0018 fatalities. Occupational health and safety numbers are explicitly reported for subsurface construction during the operations phase, as shown in Table C-7. During the operations phase, subsurface construction results in occupational health and safety impacts of 87.08 TRC, 37.29 LWC, and 0.024 fatalities.

Table C - 6
FTE During Construction Phase (2012 – 2016)

	FTEs
Subsurface Craft FTE	335.75
Total FTE	5886
Subsurface Craft Fraction	0.057

Table C - 7
Estimated Worker Health and Safety Impacts During Construction and Operation

Construction Phase – Total Impacts	**Cases**
TRC	117.2
LWC	50.2
Fatalities	0.032
Construction phase – subsurface construction only (calculated)	**Cases**
TRC	6.69
LWC	2.86
Fatalities	0.0018
Operations phase - subsurface construction	Cases
TRC	87.08
LWC	37.29
Fatalities	0.024

Summing the non-radiological impacts associated with construction of subsurface facilities during the construction and operations phases, EPRI calculated impacts of 97.77 TRC, 40.14 LWC, and 0.026 fatalities as shown in Table C-8. Assuming that the total excavated drift length in the repository is 67,915 meters, EPRI calculated the number of worker impact cases per meter as shown in Table C-8. Assuming that each waste package occupies a drift length of

approximately 5.6 meters as discussed previously in Appendix B.7, EPRI estimates the number of worker impact cases per waste package emplaced.

Table C - 8
Unit Non-Radiological Occupational Risks Associated with Subsurface Construction

Worker Impacts	Cases	Cases per Emplacement Meter	Cases per Waste Package Emplaced
TRC	93.77	1.4×10^{-3}	7.7×10^{-3}
LWC	40.15	5.9×10^{-4}	3.3×10^{-3}
Fatalities	0.026	3.8×10^{-7}	2.1×10^{-6}

C.3.5 Non-Radiological Impacts Associated with Drip Shield Installation

The YMSEIS assumes a staffing level of 10 persons per year associated with drip shield installation. The repository closure phase is assumed to last for 10 years, although it is not clear from the YMSEIS whether the drip shield installation operations will take place during the entire 10-year operations-closure phase. On annual basis, then, non-radiological impacts to workers during drip shield installation are calculated as follows using DOE's industrial safety statistics for a 10 FTE workforce:

- TRC 0.82 per year
- LWC 0.54 per year
- Fatalities 0.0018 per year

Thus, over an assumed five year period for drip shield installation there would be 4.1 TRC, 2.7 LWC, and 0.009 fatalities. If drip shield installation takes place over a ten-year period, the estimated non-radiological worker impacts would be 8.2 TRC, 5.4 LWC, and 0.018 fatalities.

C.3.6. Non-Radiological Impacts Associated with Over-Design of Surface Facilities for Seismic Considerations

Due to the classification of facility details as "Official Use Only" resulting in their omission from the publicly available version of the License Application, EPRI attempted to evaluate the occupational consequences on a more generic, semi-quantitative level using a stylized approach based on the available dimensions for the WHF footprint, typical above-grade height, and wall thickness. EPRI assumed for the purpose of this illustration a WHF facility comprised solely of a rectangular concrete shell. As part of this approach, EPRI ignored the contributions from roof, base mat/pad, and interior walls. The data and assumptions are listed below:

- Dimensions from DOE , 2008 LA (DOE, 2008c; p. 1.2.5-3):
  - ITS footprint of waste handling facility = 385 ft. x 300 ft.
  - Typical height of facility above grade = 80 ft.
  - Exterior wall thickness = 4 ft.
- Conservative assumptions:
  - a simple four sided building shell with above dimensions
  - not considering contribution of internal walls (unknown)

- not considering contribution of base mat/foundation/pool structures (assume to be appropriate)
- not considering contribution of roof (unknown/assume to be appropriate)
- not considering shrinkage of concrete upon drying

- Other Assumptions
  - neglecting volume consumed by rebar, openings (more than offset by conservative simplification of building)
  - capacity of a typical ready mixed concrete truck = 20 cu yd. or 540 cu. ft. (Clark et al., 2001)

Using these assumptions and data, the resulting volumes are calculated:

- Total wall volume = 438400 cu. ft. = 812 truck loads
- Volume reduction for 10% reduction in wall thickness = 43840 cu. ft. = 81 truck loads
- Volume reduction for 25% reduction in wall thickness = 109600 cu. ft. = 203 truck loads

Any unnecessary and unjustified conservatism in the construction of WHF and other surface pre-closure facilities result in incremental increases in worker risk due to well-documented occupational hazards. In addition to the often repeated fact that the construction industry is a perennial leader in occupational injury and fatality rates, the Bureau of Labor Statistics has also singled out three specific occupations that exhibited exceptionally high fatality rates in 2005: structural iron and steel workers, truck drivers, and construction laborers.

Table C - 9
Selected Occupations with High Fatality Rates for 2005 (BLS, 2006a)

	Fatalities (per 100,000)
Structural iron and steel workers	55.6
Driver/sales workers and truck drivers	29.1
Construction laborers	22.7

The reinforcement of concrete structures to withstand seismic loads directly involves the contribution of all three of these high-risk occupations for the preparation of appropriate concrete forms, assembly of additional rebar, and pouring of additional concrete. Additional concrete also results in additional truck deliveries that could number in the 100's to 1000's for the case of an over-designed facility. Accordingly, the purposeful over-design (beyond standard engineering margins) for seismic or any other hazard represents unnecessary and unjustified imposition of risk to the involved workers.

Table C - 10
Relevant BLS[a] and DOE[b] Non-radiological Injury and Fatality Rates

Category	TRC	LWC	Fatalities
BLS - construction	6.3	3.4	11.0
BLS - warehousing and storage	8.2	5.4	17.6[c]
BLS - truck transportation	6.1	3.9	17.6[c]
DOE - construction period[b]	2.0	0.86	0.55

[a]BLS, 2006a,b
[b]DOE 2008a, Table 4-16), Section 4.1.7.1
[c]Fatalities for transportation and warehousing category, NAICS code 48-49

It should be noted that DOE's injury and fatality rates are substantially lower that reported by BLS. DOE does not differentiate between specific trades and occupations such as iron workers.

In addition to occupational consequences, the over-design of facilities also consumes significant quantities of materials and resources that would have beneficial uses elsewhere, especially in terms of concrete (cement and aggregate) and rebar (iron/steel).

C.4 Non-Radiological Impacts Associated with a One-Year Delay of CSNF Shipment to Yucca Mountain

The major consequence of a delay in Yucca Mountain becoming operational is that existing inventories of CSNF will remain for a longer period of time at reactor sites and other commercial facilities and additional quantities of CSNF will need to be stored in both wet and dry storage. These burdens result in additional occupational health risk to workers at reactor storage sites (and other commercial facilities) associated with fuel, canister, and cask handling operations, onsite transport and emplacement operations, routine surveillance and maintenance activities, and construction of additional storage capacity. For this report, EPRI focused on the ISFSI related activities.

The YMSEIS assumes that there are 75 commercial reactor sites. Accordingly, EPRI estimates the industry wide non-radiological impacts of a one-year delay of CSNF shipments to Yucca Mountain by extrapolating the impacts described in Sections C.1.2 and C.1.3 of this Appendix for ISFSI operation and expansion, respectively, to the SEIS inventory of 75 reactor sites, assuming that each reactor site would have an operational ISFSI by the 2020 time period. These results are summarized in Table C-11.

Table C - 11
Industry Wide Non-Radiological Impacts Associated with a One-Year Delay

Activity	Annual Injuries and Fatalities (cases)
ISFSI Surveillance and inspection	0.052 TRC 0.027 LWC 4.1×10^{-5} fatalities
ISFSI Maintenance	0.052 TRC 0.027 LWC 4.1×10^{-5} fatalities
Additional storage module construction at existing ISFSI[a]	7.5 – 10 TRC 4.2 – 5.7 LWC 0.013 – 0.0189 Fatalities
ISFSI pad construction[b]	22 TRC 12 LWC 3.9×10^{-4} fatalities

[a]Based on TN-32 horizontal storage module (Rollins, 1998) and annual requirement of 160 – 200 dry storage systems for 75 commercial reactor sites.

Additionally, in the event that either existing ISFSI pad capacity at a particular site is full or does not exist, the construction of a new pad could become necessary. Table C-12 includes the non-recurring occupational consequences associated with the construction of one ISFSI pad from Section C.1.3.

Table C - 12
Non-Radiological Impacts Associated with a the Need to Construct One Additional ISFSI Pad

Activity	Total Injuries and Fatalities (cases)
ISFSI pad construction[b]	22 TRC 12 LWC 3.9×10^{-4} fatalities

[b]Based on 7090 person-hours estimate for construction of one ISFSI pad for storage of up to 28 TN-32 horizontal storage modules (Dominion, 2002).

C.5 References

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D
REPOSITORY SUBSURFACE EXCAVATION

The EPRI analysis presented in this report relies upon assumptions, estimates, and specifications pertaining to subsurface excavation and construction. For clarity, these are summarized below.

Projected Repository Subsurface Construction Requirements (DOE, 2008):

- Total drift length = 67,915 m
- Total drift length for emplacement of WPs = 65,209 m
- Drift diameter = 5.5 m
- Average/typical emplacement drift length = 600 m
- Approx. number of emplacement drifts = 108 in 4 panels
- Total volume of excavated rock = 6.5×10^6 m^3
- Volume of excavated rock for emplacement of WPs = 6.2×10^6 m^3
- Average length for 1 WP = 5.6 m
- Volume of excavated rock per meter of drift = 24 m^3
- Volume of excavated rock per average waste package = 133 m^3

Excavation volumes calculated assuming cylindrical geometry

- Total number of waste packages for emplacement (in TSPA) = 11,629
- Total number of TADs for emplacement = 7,400

Reference

DOE 2008. Yucca Mountain Repository License Application. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, DOE/RW-0573, Rev. 0, June 2008.

E
MATERIALS AND IMPACTS ASSOCIATED WITH KEY REPOSITORY SYSTEMS

Overly conservative design and certain operational decisions will result in the consumption of materials and manufacture and shipping of additional heavy components to either utility sites or Yucca Mountain, incurring non-trivial risks to workers as well as the public.

Overdesign of Yucca Mountain surface and sub-surface facilities incurs an additional, unnecessary risk burden to workers for every additional cubic meter of concrete poured and each meter of rebar used. While EPRI does not calculate total additional risk associated with such conservatism in the repository design, it is clear that such risks are significant in that the construction industry is routinely cited as one of the most hazardous occupations by the Bureau of Labor Statistics.

There are two primary scenarios for which impacts from manufacturing and transportation of heavy components are pertinent:

- unnecessary use of titanium drip shields, and
- additional emplacement drift construction and the associated infrastructure required by the disposal of smaller waste packages (i.e., containing less CSNF than necessary).

E.1 Unnecessary Use of Titanium Drip Shields

By invoking the use of drip shields, the DOE is incurring substantial resource demands for titanium, a material of significant strategic importance and of limited domestic availability. DOE estimates that its projected schedule for drip shield manufacture will result in consumption of 22% of present day annual U.S. production of Ti for a limited period of time as shown in Table E-1. Moreover, manufacture of the drip shields incurs occupational risks to involved workers. The YMSEIS (DOE, 2008a) estimates that 11,500 drip shields will be used under the Proposed Action. And as a heavy component, the YMSEIS assumes that 25 drip shields will be shipped per rail car, with a total of 460 shipments. The YMSEIS assumed a shipping distance of 3,464 km, resulting in pollution health effect fatalities of 0.028 and vehicle fatalities of 0.036 – or *total fatalities of 0.064 associated with the transport of drip shields from manufacturing facilities to the proposed repository.* (DOE 2008b, Transportation File, Attachment 12, Other materials.

In addition to the fatalities associated with transport of the drip shields, offsite manufacturing of 11,500 drip shields is estimated to take3.5 million labor hours. The YMSEIS analysis of off-site manufacturing health and safety impacts assumed 9.1 injuries per 100 full-time worker years and 3.29 fatalities per 100,000 worker years. *This results in 159 injuries and 0.609 fatalities associated with off-site manufacturing of the drip shields.* (DOE 2008b, Offsite Manufacturing File, Attachment A.)

Table E - 1
Materials Required for Repository Construction and Component Manufacturing (DOE, 2008a Final SEIS, Tables 4-30, 4-36

Material	Quantity	Proj. percentage of U.S. annual production
Concrete	490,000 m^3	
Cement	190,000 metric tons	
Carbon Steel	280,000 metric tons	
Copper	670 metric tons	
Copper*	140	0.0004%
Titanium*	54,000 metric tons	22%
Chromium*	100,000 metric tons	1.8%
Nickel*	120,000 metric tons	3.6%
Molybdenum	27,000 metric tons	1.9%

*Quantities are for repository components only, not total repository construction.

E.2 Additional Infrastructure to Support Additional Waste Package Emplacement

Each additional (unnecessary) WP emplaced at YM would require 5.6 m of drift and associated infrastructure, including one emplacement pallet, DS segment, and one TAD canister with outer waste package. The total quantities of materials associated with repository construction and component manufacture are summarized in Table D-1. Table E-2 summarizes the total number of repository components manufactured offsite. The YMSEIS estimates total worker injuries of 1,686 and total worker fatalities of 0.61 associated with manufacture of offsite components under the health and safety impact assumptions identified in the note on Table E-2.

The YMSEIS analysis of off-site manufacturing health and safety impacts assumed 9.1 injuries per 100 full-time worker years and 3.29 fatalities per 100,000 worker years. Assuming that the manufacturing of off-site components takes a total of 37 million labor hours and an average worker year is 2000 hours, the YMSEIS calculated total worker years of 18,500, resulting in 1,685 injuries and 0.61 fatalities associated with off-site manufacturing. (DOE 2008b, Offsite Manufacturing File, CalcPkg_Manufacturing1_AttchA.xls).

E.3 References

DOE 2008a. Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F-S1, LSN #: DEN001593669.

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Table E - 2
Repository System Components Manufactured Off-Site

Component	Materials	Number	Weight (Metric tons)	Number of Shipments
Waste Packages (outer)	Alloy 22	11,200	22-34	5,589
TAD Canisters	Stainless steel	7,400	29 - 31	3,700
Emplacement pallets	Alloy 22 and stainless steel	11,200	2	5,302
Titanium drip shields (section)	▪ Grade 7 Ti – surface plates ▪ Grade 29 Ti- structural components ▪ Alloy 22 - base	11,500	4.9	460
Aging overpacks (carbon steel components)	Carbon steel liner and shell	2,500	43	1,250
Note: The YMSEIS estimates health and safety impacts associated with off-site manufacturing of repository components to be 3.3 fatalities per 100,000 worker years; 9.2 illness/injuries per 100 FTE. A 24 year manufacturing period is assumed for all components except drip shields. Drip shields are manufactured over a 10 year period.				

Source: DOE 2008a, Section 4.1.14.2; DOE 2008b, Offsite Manufacturing File, Attachment A.

F

METHODOLOGY FOR EPRI'S INDEPENDENT PROBABILISTIC VOLCANIC HAZARD ANALYSIS

EPRI has recently conducted an independent assessment of the likelihood of a future volcanic event occurring at the proposed Yucca Mountain repository site. A more detailed report on this issue will be released later this year. The assessment methodology adopted in the EPRI study was based on same methodology applied in the 1996 Probabilistic Volcanic Hazard Analysis (PVHA) report (CRWMS M&O, 1996, pp. 2-19). The purpose of EPRI's study was to independently develop new insights and probability estimates for future volcanism based on the more recent, extensive geological and structural data obtain in the last 12 years in the Yucca Mountain region (YMR).

EPRI's PVHA study includes consideration of new geochemical, geophysical, seismological, geodetic and age-dating data collected since the 1996 PVHA report (e.g., Brocher et al., 1998; Day et al., 1998; Perry et al. 1998; Fridrich, 1999; Fridrich et al. 1999; Potter et al., 2002; 2004; Perry et al., 2005; Valentine et al., 2005; 2006; Parson et al., 2006; Valentine and Krough, 2006; Valentine and Perry, 2006; Gaffney et al., 2007; Perry, 2007; Valentine and Perry, 2007; Valentine et al. 2007; Keating et al, 2008). In particular, EPRI's calculation includes information from drilling (Perry et al., 2005; Perry, 2007) and characterization (i.e. age dating) of various anomalous features identified by recent high resolution aeromagnetic surveys (O'Leary et al., 2002; Perry et al., 2005) buried under alluvial deposits that have been speculated to be additional volcanic centers (Perry et al, 2004; Smith and Keenan, 2005). Furthermore, EPRI's independent update to the 1996 PVHA report includes consideration of structural factors that demonstrably have controlled the actual eruptive location of volcanic centers that have occurred in the Yucca Mountain region in the last 12 million years (Valentine and Perry, 2006; 2007; Gaffney et al., 2007; Keating et al, 2007). As noted by the NRC's Advisory Committee and Nuclear Waste (ACNW) report on volcanism (ACNW, 2007, pp. 63), for example, there has been no igneous intrusion into Yucca Mountain block in the last 10 million years.

The approach taken by EPRI follows that used in the 1996 PVHA (CRWMS M&O, 1996). The approach involves defining an igneous (volcanic) event that may intersect the footprint of the proposed repository within the next 10,000 to 1,000,000 years. The calculation requires that an igneous event be well defined and its characteristic features be quantified, and the identification of factors that govern the location and timing of a possible future igneous event in the YMR. By following a similar approach as the 1996 PVHA calculation, results from EPRI's calculation may be compared and evaluated to results in the 1996 PVHA (CRWMS M&O, 1996) and a planned PVHA-U (the updated version of the 1996 PVHA) by the DOE. The estimated annual frequency of intersection in the 1996 PVHA (CRWMS M&O, 1996) is expressed as:

$$\nu = \frac{N(R,T)}{T} \cdot \frac{a_r}{A_R}$$

where, N(R,T) is the number of events that have occurred in region R in time period T, A_R is the area of region R and a_r is the area of the repository. The above equation is expanded to the following expression to account for alternative temporal and spatial models (CRWMS M&O, 1996):

$$\nu = \iint_R \int\int \lambda(x,y,z)\, P_l(x,y)\, dx\, dy = \frac{N(R,T)}{TA_r} \iint_r dx\, dy = \frac{N(R,T)}{T} \cdot \frac{a_r}{A_R}$$

where, $\lambda(x,y,t)$ is the rate density function (frequency of events per unit time per unit area), and P_l is the conditional probability (for a point source event, $P_l = 1$ inside the effective region of interest *r*, and 0 everywhere else). $\lambda(x,y,t)$ is separated into two parameters: $\lambda(t)$, rate parameter ($N(R,T)/T$), and $f(x,y)$ spatial density ($1/A_R$). The probability calculation requires an understanding of an expected igneous event in the area of interest as well as an assessment of the spatial and temporal parameters.

The framework for EPRI's probability calculation is divided into fours steps. The first step is a review of recent data and development of EPRI's independent *conceptual model* for an expected igneous event in YMR in the next 10,000 to 1,000,000 years. The second step *defines EPRI's expected igneous event* that may intersect the repository including its characteristic features. The third step identifies EPRI's *region of interest* and factors that influence the spatial occurrence of an expected igneous event using a logic tree to illustrate alternative spatial as well as temporal models. The fourth step identifies and discusses the *time* of interest and *duration* of events.

For its Step 1 development of an independent conceptual model, EPRI evaluated trends in Yucca Mountain field data that includes geochemistry, volume, and location of volcanoes in YMR, as well as recent tectonic models, EPRI believes that if an eruption were to occur in YMR in the next 10,000 to 1,000,000 years, it would occur within the Crater Flat area, along a pre-existing fracture oriented perpendicular (N30E) to the least compressive stress field of the region and with a dip angle approaching vertical. The volcanic material would be alkali basalt, with eruption characteristics similar to volcanoes located within the Crater Flat area typified by the Lathrop Wells volcano. Furthermore, extensional trends in the YMR indicate the NE part of the basin (i.e., the location of the repository) will be less prone to future eruptions than the SW region.

"Event definition" in EPRI's Step 2 describes the expected ranges in characteristics of an igneous event that could intersect the repository at its proposed depth of 200-300 m below the surface of Yucca Mountain. At repository depths, the intrusion of igneous material occurs as a sheet-like dike; if this dike reaches the surface, the initial linear fissure eruption rapidly evolves into a eruptive conduit that can lead to formation of a scoria cone. Therefore, EPRI considers only dikes in its event definition; sills and conduits are considered to be features that develop after a dike has reached the surface. Important dike characteristics in the EPRI event definition include dike length and dike azimuth.

The region of interest (Step 3) in EPRI's PVHA analysis is defined by two areas, one large area and one smaller region. The larger region encompasses areas around the Yucca Mountain block in which the repository is located, to include Jackass Flats to the east, areas north such as Thirsty Mesa and Sleeping Buttes volcanoes, and areas south into the Amargosa Valley, and areas west bounded by the Bare Mountain fault. The smaller region considered by EPRI is essentially the Crater Flat structural domain with boundaries defined by faults: the Bare Mountain fault to the west, the Yucca Mountain fault to the north and the Gravity fault to the east. The larger region is

used to evaluate each volcanic event in YMR with respect to event definition and its relevance on the spatial and temporal models for predicting a future igneous event. The smaller region defines EPRI's area of interest for its spatial model.

Two spatial models are considered in the EPRI analysis; a Fault Capture Model, and a No Fault Capture Model. The Fault Capture Model is based on recent DOE studies that demonstrate how low volume (< 1.0 km^3) magmas tend to ascend through the crust along the path of least resistance (Valentine and Perry, 2006; 2007; Gaffney et al., 2007; Keating et al, 2008). Initially magma will migrate through the lithosphere as a self-propagating dike following a direction (N30E in the YMR) that is perpendicular to the regional least compressive stress direction. As the dike approaches the surface, it will intersect and follow a fracture with a similar azimuth (N30E) and a steep dip angle (> 60°). In EPRI's Fault Capture Model, only pre-existing faults are considered as probable locations for dikes and relative probabilities are assigned to faults that have been mapped in the Yucca Mountain region (Day et al., 1996; Potter et al., 2002; 2004; Perry, 2007) based on fault azimuth relative to the regional stress field (Stock et al., 1985). As an alternative, EPRI also considers a No Fault Capture Model in which it is assumed magma will ascend in a self-propagating dike that will reach with little influence from the pre-existing structure or topography. The dike will follow a path that is perpendicular to the least compressive stress direction. Probability distribution for event azimuth is assigned with respect to the regional stress field. This alternative model accounts for the uncertainty of an event that may not follow the Fault Capture Model. Both models consider lithostatic pressure and cumulative extension data in their evaluation of the location of a future event.

Finally, in Step 4 EPRI also considers temporal relationships and patterns of past eruptions as models for possible future eruptions in the YMR. In brief, EPRI evaluates two temporal conceptual models, one referred to as the Spatial Cluster Model and the other the Fault Initiated Cluster Model. The Spatial Cluster Model assumes that events are controlled by a regional tectonic event that initiates partial melting in the lithospheric mantle in one of the structural domains with the YMR. The Fault-Initiated Cluster Model assumes expected events are associated with localized fault movement.

Based on the more recent geological and structural data obtained by the US DOE (i.e., Valentine et al., 2005; 2006; Parson et al., 2006; Valentine and Krough, 2006; Valentine and Perry, 2006; Gaffney et al., 2007; Perry, 2007; Valentine and Perry, 2007; Valentine et al. 2007; Keating et al, 2008) and its own independent spatial and temporal models for controlling factors for the occurrence and eruption of igneous (volcanic) events, EPRI calculated a time-dependent probability of a future event intersecting a repository at Yucca Mountain (see Figure E-1). For a time 10,000 years after repository closure, EPRI's estimated range for igneous-event probability is 0.0 to 1.3×10^{-8} per year, with a mean value of 3.7×10^{-9} per year. For a period 1,000,000 years after repository closure, the estimated range for igneous-event probability is 0.0 to 7.3×10^{-9} per year, with a mean value of 3.0×10^{-9} per year. The decrease in probability values between 10,000 and 1,000,000 years (Figure F-1) is attributable to the time-dependent influence of EPRI's Spatial Cluster Model (i.e., events triggered by regional tectonic episode) imposed on the baseline of the Fault-Induced Cluster Model.

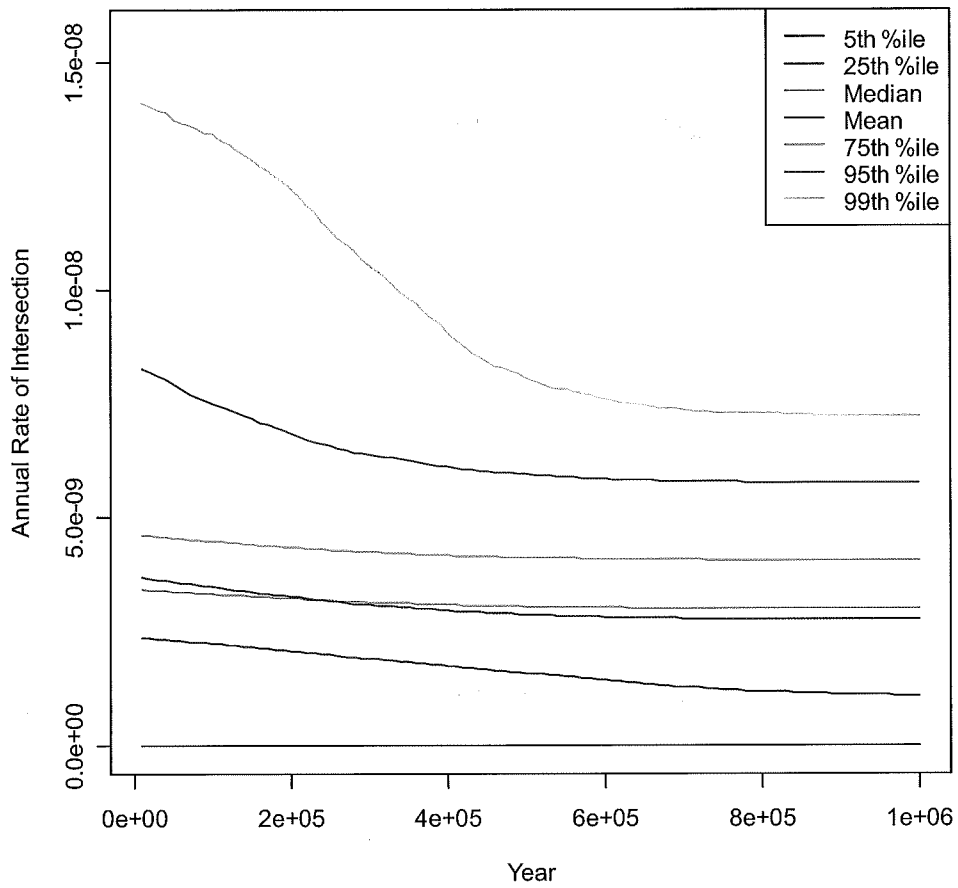

Figure F - 1
Calculated Probability for a Future Igneous Event Intersecting a Repository Located at Yucca Mountain, Nevada

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G
POTENTIAL ECONOMIC IMPACTS

In additional to the radiological and non-radiological impacts associated with DOE's decision to utilize the 21P/44B TAD canister rather than higher capacity canisters, there will also be economic impacts for nuclear operating companies. These economic impact include:

- Increased costs associated with loading additional packages at reactor sites
- Increased costs associated with transporting additional CSNF casks
- Increased costs to the DOE program associated with
    - The purchase of additional TAD canisters for transport, aging, and disposal
    - The purchase of additional waste packages for CSNF

EPRI has estimated the increased costs associated with DOE's decision to utilize the 21P/44B TAD canister rather than higher capacity canisters, as discussed in the sections below.

Under EPRI Case 1 assumptions, cost savings associated with using higher capacity TADs were estimated to be:

▪ At reactor loading costs	$0.38 billion
▪ Transport costs	$0.33 billion
▪ Disposal costs	$3.14 billion
▪ Total potential savings:	$3.85 billion

Unde rEPRI Case 2 assumptions, cost savings associated with using higher capacity TADs and assuming a minimal amount of CSNF is shipped by truck were estimated to be:

▪ At reactor loading costs	$0.44 billion
▪ Transport costs	$0.41 billion
▪ Disposal costs	$3.33 billion
▪ Total potential savings	$4.18 billion

G.1 Increased Cost Associated With Cask Loading and Handling At Reactor Sites

In calculating the costs associated with loading CSNF at reactor sites, EPRI assumed that TADs and DPCs would have a loading cost of $200,000 per package. Truck casks were assumed to have a loading cost of $50,000 per package. Using the number of packages estimated by EPRI in Appendix A, EPRI estimates that under EPRI Case 1, loading costs at reactor sites could be reduced by $0.38 billion if DOE adopted larger capacity TAD packages rather than the 21P/44B TAD design as shown in Table G-1. Under EPRI Case 2, loading cots at reactor sites could be reduced by $0.44 billion if DOE adopted a larger capacity TAD package and truck sites idenfied by DOE in the YMSEIS instead shipped CSNF in large capacity TADs.

DOE's YMSEIS assumes that all TADs loaded with CSNF at reactor sites will be stored at reactor ISFSIs prior to being transported to the repository for disposal. Thus, in addition to the increased costs associated with loading a greater number of 21P/44B TAD canisters, there will be an increase in the size of the ISFSI storage pad needed to store the additional TAD packages at reactor sites, compared to storing a smaller numer of higher capacity TADs or DPCs. EPRI has not attemped to quanitify the incremental ISFSI pad construction costs associated storing additional 21P/44B TAD packages at reactor sites since these costs would be site specific.

Table G - 1
Estimated Costs Associated with Cask Loading and Handling At Reactor Sites

Package Type	Loading Cost/Package	DOE YMSEIS	EPRI Case 1	EPRI Case 2
TAD 21P/44B	$200,000	$1.3 billion		
Large Capacity TAD 24P/32P,61B,68B	$200,000		$0.92billion	$0.99 billion
DPC	$200,000	$0.06 billion	$0.06 billion	$0.06 billion
Truck	$50,000	$0.13 billion	$0.13 billion	0
Total Cost		$1.49 billion	$1.11 billion	$1.05 billion
Cost Reduction			$0.38 billion	$0.44 billion

G.2 Increased Costs Associated With Transporting CSNF

The YMSEIS calculated a 2,833 total rail shipments (assuming three casks per train) for CSNF, DOE and Navy SNF, and HLW; and 2,650 truck shipments. As summarized in Table G-2, under EPRI Case 1 there would be an estimated 2,074 rail shipments, assuming three casks per train, and 2,650 truck shipments. Under EPRI Case 2 there would be an estimated 2,186 rail shipments (assuming 3 casks per train) and 2 truck shipments. The estimated rail shipments in the DOE YMSEIS, EPRI Case 1 and EPRI Case 2 include shipments of CSNF, DOE and Navy SNF, and DOE HLW.

DOE's July 2008, "*Analysis of the Total System Life Cycle Cost (TSLCC) of the Civilian Radioactive Waste*" (DOE 2008c) assumes that the costs for transport operations execution will be $3.12 billion to transport a total of 4,239 truck casks and 16,619 rail casks containing CSNF, DOE HLW and DOE SNF. EPRI estimated the unit costs per cask transported using data from DOE's 2008 TSLCC. EPRI assumed that the cost to transport one truck cask from reactor sites to Yucca Mountain would be $50,000. Thus, using DOE's data from the 2008 TSLCC, truck cask transportation would account for $211.95 million out of the total $3.12 billion. Dividing the remaining $2.91 billion by 16,619 rail casks assumed in the 2008 TSLCC, results in a cost per rail cask shipment of $175,100 per cask. It should be noted that the number of shipments in the 2008 TSLCC is higher than those considered by EPRI in this report since the 2008 TSLCC is based on total CSNF arisings of 109,300 MTU as well as all of the DOE SNF and HLW, and Navy SNF. EPRI's analysis considers the quantities of CSNF considered under the Proposed Action for a 70,000 MTU repository.

As shown in Table B-5, under the assumptions in the YMSEIS, the cost to ship CSNF would be approximately $1.324 billion. If rail shipments of CSNF utilized higher capacity casks than the 21P/44B TAD design as assumed in EPRI Case 1, the estimated cost to transport CSNF would be $990 million, a reduction of $334 million compared to cost for shipment of CSNF using the 21P/44B TAD. If rail shipments of CSNF utilized higher capacity TADs and the truck sites identified in the YMSEIS instead shipped by higher capacity TADs, the estimated cost to transport CSNF would be $917 million, a reduction of $407 million compared to cost for shipment of CSNF using the 21P/44B TAD and truck casks.

Table G - 2
Estimated Costs Associated with Transport of CSNF to Yucca Mountain

Scenario	Number of Casks	Estimated Transport Cost (Millions $)
DOE YMSEIS (70,000 MTU)		
▪ **Rail Casks Shipped**	6,806	$1,192
▪ **Truck Casks Shipped**	2,650	$132
Total Transport Cost		$1,324
EPRI Case 1		
▪ **Rail Casks Shipped**	4,898	$858
▪ **Truck Shipped**	2,650	$132
Total Transport Cost		$990
EPRI Case 2		
▪ **Rail Casks Shipped**	5,235	$917
▪ **Truck Shipped**	4	$0.2
Total Transport Cost		$917

G.3 Increased Costs To Handle and Disposal of CSNF

The YMSEIS assumed that a total of 7,400 TADs would be used for CSNF disposal under the proposed action (DOE 2008a, Table 4-32). As noted in Appendix A, the YMSEIS assumes that a total of 6,499 TADs are loaded with CSNF at reactor sites, leaving a total of 901 TADs to be loaded with commercial SNF that is shipped in the 307 DPCs and 2,650 truck casks. Under EPRI Case 1, a total of 4,591 higher capacity TADs are assumed to be loaded at nuclear power plant sites. If the CSNF shipped to the repository in DPCs and truck casks are repackaged at the repository into higher capacity TAD packages (32P, 68B), EPRI estimates that 489 packages would need to be loaded at the repository. Under EPRI Case 2, a total of 4,928 higher capacity TADs are assumed to be loaded at reactor sites. Under this scenario, there were two truck casks containing CSNF, which is assumed to be transferred to 1 TAD canister at the repository.

The 2008 TSLCC assumes that a PWR TAD will cost $700,000 and a BWR TAD will cost $800,000. For simplification, EPRI assumed an average TAD cost of $750,000. Under the YMSEIS assumptions, EPRI estimates that the cost of TAD canisters to dispose of CSNF would be $5.55 billion. Under EPRI Case 1, EPRI estimates that the cost of 5,080 larger capacity TAD canisters would be $3.81 billion, a reduction of $1.74 billion. Under EPRI Case 2, EPRI estimates that the cost of 4,929 larger capacity TAD canisters would be $3.70 billion, a reduction of $1.85 billion.

The YMSEIS calculation package assumed that the unit cost for TAD waste packages would be $600,000 (DOE 2008b, Offsite Manufacturing File, CalcPkg_Manufacturing1_AttchA.xls). Using the scenarios described in Table G-3, under the YMSEIS assumptions, EPRI estimates that the cost of TAD waste packages for disposal of CSNF would be $4.44 billion. Unde EPRI Case 1, EPRI estimates that the cost of 5,080 larger capacity TAD waste packages would be $3.04 billion, a reduction of $1.4 billion. Under EPRI Case 2, EPRI estimates that the cost of 4,929 larger capacity TAD canisters would be $2.96 billion, a reduction of $1.48 billion. As shown in Table G-3, the overall cost savings associated with the use of higher capacity TAD designs would be $3.14 billion under the assumptions in EPRI Case 1 and $3.33 billion under the assumptions in EPRI Case 2.

Table G - 3
Estimated Costs Associated with Disposal of CNSF in TAD Canisters

Scenario Description	Number of TADs	TAD Canister Cost (Billions $)	Waste Package Cost (Billions $)	Tota Cost (Billions $)
DOE YMSEIS (70,000 MTU)				
TADs Loaded at Reactors	6,499	$4.87	$3.90	
TADs Loaded at Repository	901	$0.68	$0.54	
Total Cost		$5.55	$4.44	$9.99
EPRI Case 1				
TADs Loaded at Reactors	4,591	$3.44	$2.75	
TADs Loaded at Repository	489	$0.37	$0.29	
Total Cost		$3.81	$3.04	$6.85
EPRI Case 2				
TADs Loaded at Reactors	4,928	$3.70	$2.96	
TADs Loaded at Reposiotry	1	$0.00	$0.00	
Total Cost		$3.70	$2.96	$6.66

G.4 References

DOE 2008a. Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F-S1, LSN #: DEN001593669.

DOE 2008b. Yucca Mountain Supplemental Environmental Impact Statement: Calculation Packages in Support of Final Supplemental Environmental Impact Statement for a Geologic

Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F-S1.

DOE 2008c. U.S. DOE, OCRWM, Analysis of the Total System Life Cycle Cost (TSLCC) of the Civilian Radioactive Waste Management Program, DOE/RW-0591, July 2008.

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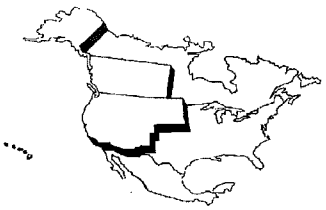
ATTACHMENT 14



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Summary of the April 22-23, 2008 Meeting of the High-Level Radioactive Waste Committee, in Tempe, Arizona

Eleven WIEB states participated (AZ, CA, CO, ID, NE, NV, NM, OR, UT, WA, WY). Roger Mulder, Director of the Pantex Program in the State Energy Conservation Office, represented the State of Texas. Also participating were representatives of Council of State Governments-Midwest (CSG-MW), Council of State Governments-Eastern Regional Conference (CSG-ERC), Southern States Energy Board (SSEB), and National Conference of State Legislatures (NCSL). The DOE/OCRWM Office of Logistics Management (OLM) was represented by Frank Moussa and Alex Thrower, Western Governors' Association (WGA) by Kevin Moran and Alex Schroeder, Nuclear Waste Technical review Board (NWTRB) by Karyn Severson, and Nuclear Regulatory Commission (NRC) by Earl Easton.

The agenda included:

- A joint session with WGA, on topics of mutual interest/concern.
- A states-only business meeting.
- An OCRWM program update
- A panel on National Transportation Plan issues
- A review of WIEB comments on NWPA Section 180(c)
- An update from the Nuclear Regulatory Commission
- SRG update reports
- Reports from Western States

WGA/WIEB Joint Meeting

In a joint meeting on Tuesday afternoon, the Committee received:

- A review of pending climate change legislation in Congress from Kevin Moran.
- A summary of NRC's RAMQC rulemaking and a discussion of risk communication resources, from Barbara Byron.
- A summary of a proposed pilot study to evaluate the usefulness of IRRIS (GeoSystems) in development of "rich" information on route conditions and needs, by Fred Dilger.
- A discussion of radiation specialist training programs (the Phase II Update), by Craig Halverson.

- A discussion of the clean-up progress and challenges at Hanford, by Ken Niles. This well-illustrated report reviewed the history of the Hanford site, the 1989 cleanup agreement, the extraordinary cleanup problems encountered, the cleanup progress made, and the considerable remaining challenges.
- A review of proposed and prospective enrichment and reprocessing facilities in southeastern New Mexico, by Christina Nelson.

States-Only Business Meeting

At the states-only business meeting Wednesday morning, the Committee received:

- A report on the status of the renewal of the 5-year DOE-WIEB cooperative agreement, from Jim Williams.
- A review (based on an April 8 conference call with DOE) of the basic parameters for WIEB HLW program budgets for the remainder of FY'08 and FY'09, from Jim Williams.
- An outline of WIEB budget plans for the remainder of FY'08 (including the pilot study) and for FY'09, from Doug Larson.

OCRWM Program Update

After a host state welcome from Aubrey Godwin, and an agenda review by Committee Co-chairs Barbara Byron and Joe Strolin, the Committee received an OCRWM program update from Alex Thrower (OCRWM/OLM):

- Despite the $108 million FY'08 appropriation funding reduction, the Yucca license application will be submitted in June 2008. Depending on the NRC review process, construction authorization is expected in September 2011, and an operations license application will be submitted March 2013.
- A new fee adequacy determination, a second repository report and an interim storage report will be released in the summer of 2008.
- The OLM budget will remain under $20 million until repository construction is authorized—i.e. at least until FY'12.
- DOE intends to issue the National Transportation Plan this summer. It will be "investment based"—investments are designed to create capabilities. Details will be presented in "nested" Systems Operations and Campaign Plans.
- DOE intends to expand its benchmarking efforts, as a means to identify "best practices."
- Nevada rail is intended to be operational prior to the opening of the repository, and is needed in order to ship 3000 MTHM/year.
- The railroads' routing suggestions from 12 origins to a Caliente destination are expected within a few weeks. (Rail Topic Group: Proposed Standard Problem).
- DOE has just begun to review comments on the Section 180(c) Federal register Notice. The Section 180(c) pilot project is "schedule and funding dependent."
- It is unclear how Section 180(c) will be funded. Will it be a DOE line item

request based on state needs assessments, with priorities based on queue?

National Transportation Plan (NTP) Issues

Co-chair Joe Strolin (NV) introduced the session, focusing on linkages between the Repository SEIS proposed action (68 specified sites shipping cross-country by dedicated train) and the implementation hurdles that must be address in the NTP. Among these are the allocation of acceptance slots needed to make-up dedicated trains, the implementation of the TAD canister system, the resolution of intermodal issues at numerous shipment origins, and the identification of best practice in the use of overweight trucks

- Jim Williams (WIEB) discussed "the question of queue," arguing that, while liability issues make it impractical to resolve the question now, neither can or should it be ignored, as the issue is fundamental to a best practice cross-country shipment campaign. Williams has preliminarily assessed several possible criteria for waste acceptance, considering the origins involved (and excluded), the age of SNF shipped, and the number of queue slot trades required for implementation.
- Rod McCullum (NEI) discussed DOEs Transportation-Aging-Disposal (TAD) canister system, emphasizing their role in integrating a used fuel management system. Shipping oldest-fuel-first is a "non-starter" from a business standpoint; utilities need to remove (generally younger) SNF from pools. While utilities generally support the TAD concept, they do not intend to purchase (and load) TADs until waste acceptance—i.e. 2017 or later. Meanwhile, SNF removed from pools will be placed in dual purpose canisters, which utilities do not intend to reload to TADs for shipment. SNF removed from pools for on-site dry storage will be shipped in dual-purpose canisters (DPCs), and reloaded to disposal canisters at the repository site. The number of DPCs is therefore likely to greatly exceed the 307 estimated in the Repository SEIS proposed action. TAD's reduce fuel handling at the repository and may contribute to waste confidence, but utilities do not intend to pay the incremental cost or reload DPCs before shipment.
- Bob Halstead (NV-NWPO) addressed intermodal transport issues. By his count, 22 origins require intermodal transport,[1] many of which have queue slots that could result in early shipment. Halstead argues that many issues in intermodal transport have not yet been seriously addressed, and should be addressed on a site-specific basis. He also argues that intermodal issues may complicate other transportation process, such as Section 180(c) implementation, and/or implementation of HM-232E rail routing and security

1 Of these, 7 are also listed in SEIS Table G-7; 15 are not listed. Seven origins listed in SEIS Table G-7 are not included on Halstead's list.

rules.

- Rod McCullum (NEI) made a presentation on the use of overweight trucks, and John Hauser (Tri-State) provide additional comments. Overweight trucks are 80-115,000 pounds; after delivery (i.e. without SNF) most such would be oversize but not overweight. Overweight trucks are subject to state restrictions (time of day, holidays, time of year, etc.) which may vary by state and are issued for each shipment. Overweight truck shipment occurs on a daily basis nationwide. SNF shipment by overweight truck (mostly in the 1980s) includes 31 shipments from West valley to Dresden, IL (570 miles), 33 shipments from West Valley to Oyster Creek, NJ (420 miles), and 16 shipments from Surry, VA to Idaho National Laboratory (2800 miles). Overweight truck shipment casks (e.g. GA-4/9) could be shipped by rail, but at only one cask per rail car.

NWPA Section 180(c) Federal Register Notice

Tammy Ottmer, who participated in the extensive TEC Topic Group discussion of Section 180(c), summarized the purposes behind WIEB comments on the July 2007 Federal Register Notice: a) to reflect Topic Group issue paper recommendations, negotiated principles of agreement, and relevant WGA resolutions; b) to raise again the issues of funding and funding distribution; and c) to raise again the issue of needs, in addition to training.

U.S. Nuclear Regulatory Commission Report

Earl Easton provided a report on current activities at NRC:

- NRC's response to the WGA letter on spent fuel schedules is expected in a few weeks.
- RAMQC rulemaking will begin in May 2008 and will be finalized in Spring 2009.
- NRC's "waste confidence" decision is under review to determine if revision is needed.
- The NRC package performance study continues; a decision on full-scale testing will be tied to TAD submittal and approval.
- NRC's information on cask vulnerability is currently focused on vendors, but NRC has not forgotten its commitment to the SRGs (See Oct. 15, 2007 letter.)

SRG Update

Lisa Janairo (CSG-MW) invited other SRGs to her June 18-19 meeting in Indianapolis. She hopes to update the CSG-MW transportation guide in this fiscal year. Lisa and Ken Niles are proposing a stakeholder panel at the Waste Management Conference in early 2009. There was some discussion (involving DOE) about the value of the WM Conference in general, and the stakeholder panel in particular.

Ken Niles summarized the paper presented at the February 2008 WM Conference, co-authored with Lisa Janairo: "Why DOE's Messages on Transportation Don't

Resonate With the Public." The paper explored the persistent disparity between expert and lay perceptions of risk. Considering eleven "outrage factors" in risk communication, the authors reviewed 40 DOE fact sheets, booklets and brochures, finding consistent patterns of miscommunication. The authors then made several recommendations. The paper is likely to be a key text in DOE's effort to respond to issues raised by Hank Jenkins-Smith at the February TEC meeting in San Antonio.

Reports From Western States

Nevada is developing 500-900 contentions regarding the anticipated Yucca license application. Also, Nevada will participate in the STB's review of the Nevada rail spur as an element in a national rail transportation system.

Oregon is continuing its 20-year practice of conducting a radiological training course at OSU, which has a reactor.

Nebraska is planning a training exercise in North Platte.
Idaho: Craig Halverson has monitored the nuclear plant proposals of MidAmerican energy and Alternate Energy Holdings. He reviewed his findings and suggested a future session on the changing nuclear energy context for nuclear waste transportation.

Utah: Connie Nakahara reviewed the status of litigation regarding the PFS Interim Storage Project at the Goshute Reservation. She also noted Governor Huntsman's intention to oppose the importation of Italian nuclear waste by Energy Solutions.

Washington: Larry Goldstein noted that his state appealed a ruling against Washington on waste importation.

Wyoming: Scott Ramsay discussed applications for 4 new in-situ uranium mines in Wyoming.

California: Barbara Byron mentioned the 2007 CEC report on the status of nuclear power. A bill to repeal the CA moratorium recently failed to pass in the State Legislature. The CEC is currently conducting a study on the replacement of steam generators at Diablo Canyon and San Onofre.

Wrap Up

The Committee agreed to proceed with the pilot study regarding applications of IRRIS. The Committee concurred with the general approach outlined by Doug Larson for dealing with FY'09 budget limitations. Portland was suggested as a possible location for a next meeting.

ATTACHMENT 15

Integrated System Operations

Industry Perspectives

Rod McCullum, Nuclear Energy Institute

Nuclear Waste Technical Review Board

Las Vegas, Nevada

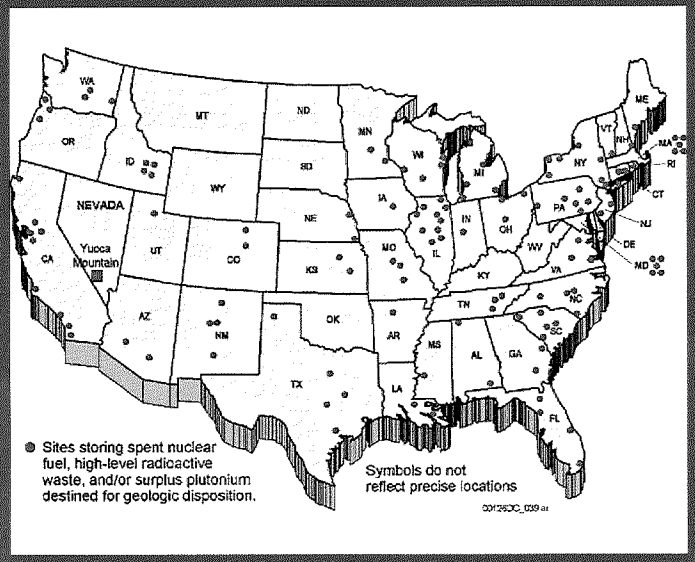
September 24, 2008

NEI

NUCLEAR ENERGY INSTITUTE

Used Nuclear Fuel Storage

- Current used fuel inventory
  - Approximately 60,000 MTU
- Current dry storage inventory
  - 11,771 MTU
  - 1017 casks/canisters loaded
  - At 47 sites
- Future dry storage by 2020
  - Estimating 25,300 MTU
  - 2,100 casks/canisters loaded
  - At 70 sites



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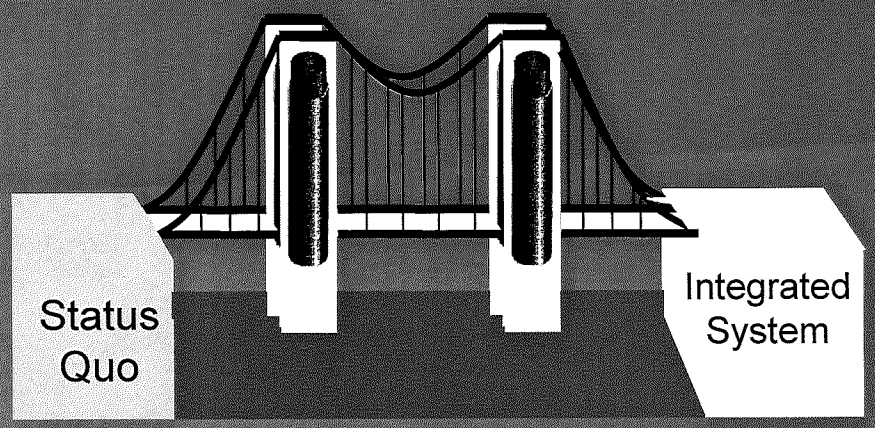
Integrated Used Fuel Management

- Three-pronged approach to used fuel management
  - Interim storage at centralized location(s)
  - Research, development, and commercial demonstration to close the nuclear fuel cycle
    - recycling used nuclear fuel
    - advanced used fuel reprocessing technologies
    - developing new type of fuel from reprocessed product
    - new reactor designs
  - Permanent disposal facility
    - Yucca Mountain site judged suitable by Congress in 2002
    - Yucca Mountain licensing process underway
- Divided into short, medium, and long term goals

NEI

Transportation, Aging and Disposal Canisters (TADs) – an integration tool



- Provide for one time loading of used nuclear fuel at the reactor site
- Connect long-term disposal goals to today's real world of used fuel management
- Are similar to dual purpose dry storage systems already in use (DPCs) – but meeting additional disposal requirements results in reduced capacity and increased costs

NEI

TAD Progress

Date	Accomplishment
11/2005	DOE presents TAD concept to industry
1/2006	DOE industry technical dialogue on TADs begins
4/2006	DOE qualifies four vendors to submit proposals for TAD designs
11/2006	DOE publishes Draft TAD Performance Specification
2/2007	Vendors complete TAD proof-of-concept designs
6/2007	DOE publishes final TAD Performance Specification
7/2007	DOE issues procurement for TAD demonstrations (Vendors are asked to submit proposals for obtaining an NRC license for a TAD and working along with a reactor owner to deploy that TAD at one or more reactor sites)
8/2007	Four vendors submit proposals for TAD demonstrations
5/2008	Two vendor teams are awarded contracts to license and deploy demonstration TADs
2013	Earliest date for commercial availability of TADs

NEI

Industry perspectives on TADs

- TAD advantages benefit industry
  - Reduced fuel handling @ repository, simplified design improves repository licensability
  - Reduced disposal and waste acceptance uncertainty
  - Increased confidence that on-site storage is *temporary*
  - Represents the first step towards integrating the overall used nuclear fuel management system
- Industry/DOE dialogue has resolved technical issues
- But will the benefits of TADs be realized?
  - TADs will only be deployed for storage at reactor sites if doing so can be justified as a sound business decision
    - DOE incentives must compensate for increased cost of TADs
  - DOE must continue to support vendors with timely decisions, uninterrupted process, and responsiveness to technical concerns
  - Industry must have confidence that Yucca licensing will continue

NEI

Systems integration beyond TADs

- DOE's "best achievable" date to open Yucca Mountain is 2020
- The nation's used fuel management system will evolve significantly between now and 2020
- The TAD experience demonstrates that specific integration strategies can be developed in relatively short time frames
- Continued demonstration work on TADs between now and 2013 will adequately position the system for the next steps at a time when it is more appropriate to begin planning those steps
  - e.g., specific system operational strategies can not be defined until the configuration of the system at the time DOE is ready to begin receiving used nuclear fuel is better known

NEI