NUCLEAR WASTE ASSESSMENT SYSTEM FOR TECHNICAL EVALUATION (NUWASTE)

Gene Rowe

Staff, U.S. Nuclear Waste Technical Review Board, 2300 Clarendon Boulevard, Suite 1300, Arlington, VA 22201
rowe@nwtrb.gov

Mark Abkowitz

Board Member, U.S. Nuclear Waste Technical Review Board, 2300 Clarendon Boulevard, Suite 1300, Arlington, VA 22201
Department of Civil & Environmental Engineering, Vanderbilt University, Nashville, TN 37235

Nigel Mote

Executive Director, U.S. Nuclear Waste Technical Review Board, 2300 Clarendon Boulevard, Suite 1300, Arlington, VA 22201

Bruce Kirstein

Staff, U.S. Nuclear Waste Technical Review Board, 2300 Clarendon Boulevard, Suite 1300, Arlington, VA 22201

Several computer software tools are available for evaluating nuclear power program scenarios and the economics of alternative fuel cycles. However, their capability to evaluate the impacts on waste management options is limited. The main purpose of the Nuclear Waste Assessment System for Technical Evaluation (NUWASTE) is to evaluate the impacts of different fuel cycle options on the radioactive waste streams that will be produced through the end of the century; assuming only present light water reactor (LWR) technology is available. This includes consideration of the following options for managing spent nuclear fuel (SNF) and high-level radioactive waste (HLW): 1) dry storage, 2) disposal in a geologic repository, 3) reprocessing and MOX and/or UOX fuel fabrication from recycled material for use in LWRs, and 4) any combination of the above. For the reprocessing options, only first cycle SNF assemblies are reprocessed; second cycle UOX fuel assemblies and first cycle MOX fuel assemblies are either disposed in a geologic repository or placed in dry storage. NUWASTE is based on a material-balance analysis that quantifies the demand for fissile material for use in the U.S. LWR fleet, the production and accumulation of SNF, and the HLW, and other wastes generated from reprocessing. More than 60 individual isotopes are tracked.

This paper describes the methodology and assumptions that comprise the basis for NUWASTE, as well as the results of preliminary scenarios that have been evaluated.

I. INTRODUCTION

The mission of the Nuclear Waste Technical Review Board (NWTRB) is to independently review the technical validity of U. S. Department of Energy (DOE) activities regarding the management and disposal of SNF and HLW generated by the commercial nuclear industry and DOE's own activities. To assist with this, the NWTRB has developed a software tool that assesses the consequences of implementing various nuclear waste disposition options. This paper describes and illustrates the capability of this tool. It should be noted that any results presented in this paper are for presentation purposes only and do not represent a recommendation by the NWTRB of any particular approach.

II. STRUCTURE

The existing United States LWR fleet and nuclear fuel discharged volumes through 2009 serves as the initial condition. Three alternative future nuclear generation capacity scenarios are used to project future SNF discharges:

1) existing nuclear power plants only,
2) existing plus the 28 additional plants for which license applications have been submitted to the Nuclear Regulatory Commission (NRC)
3) sufficient new plants to maintain the present nuclear generation capacity.

NUWASTE is based on a material balance analysis that tracks the masses of SNF and over 60 individual isotopes on a yearly basis. OrigenARP 5.1.01 is used to determine the isotopic content of the discharged SNF assemblies, and a simplified algorithm is used to determine the required isotopic content for the assemblies fabricated from the separated material. Either fresh or recycled uranium can be used for the fabrication of UOX assemblies. MOX assemblies are fabricated from recycled plutonium with uranium from one of six sources:

1) fresh uranium tails
2) fresh unenriched uranium
3) fresh enriched uranium
4) recycled uranium tails
5) recycled unenriched uranium
6) recycled enriched uranium.

In addition to the individual isotope masses, NUWASTE reports the reduction in the amount of natural uranium required, number of assemblies fabricated from recycled material, number of waste packages required, reduction in repository size, and volumes of low level and greater than class C waste generated.

A functional flowchart of NUWASTE is shown in Figure 1. There are approximately 50 variables that can be adjusted to define a specific scenario, such as average assembly burnup and enrichment, cask capacities, and allowable assembly age for reprocessing and disposal. The start dates for operation of reprocessing and geologic repository facilities, and their capacities, can be varied.

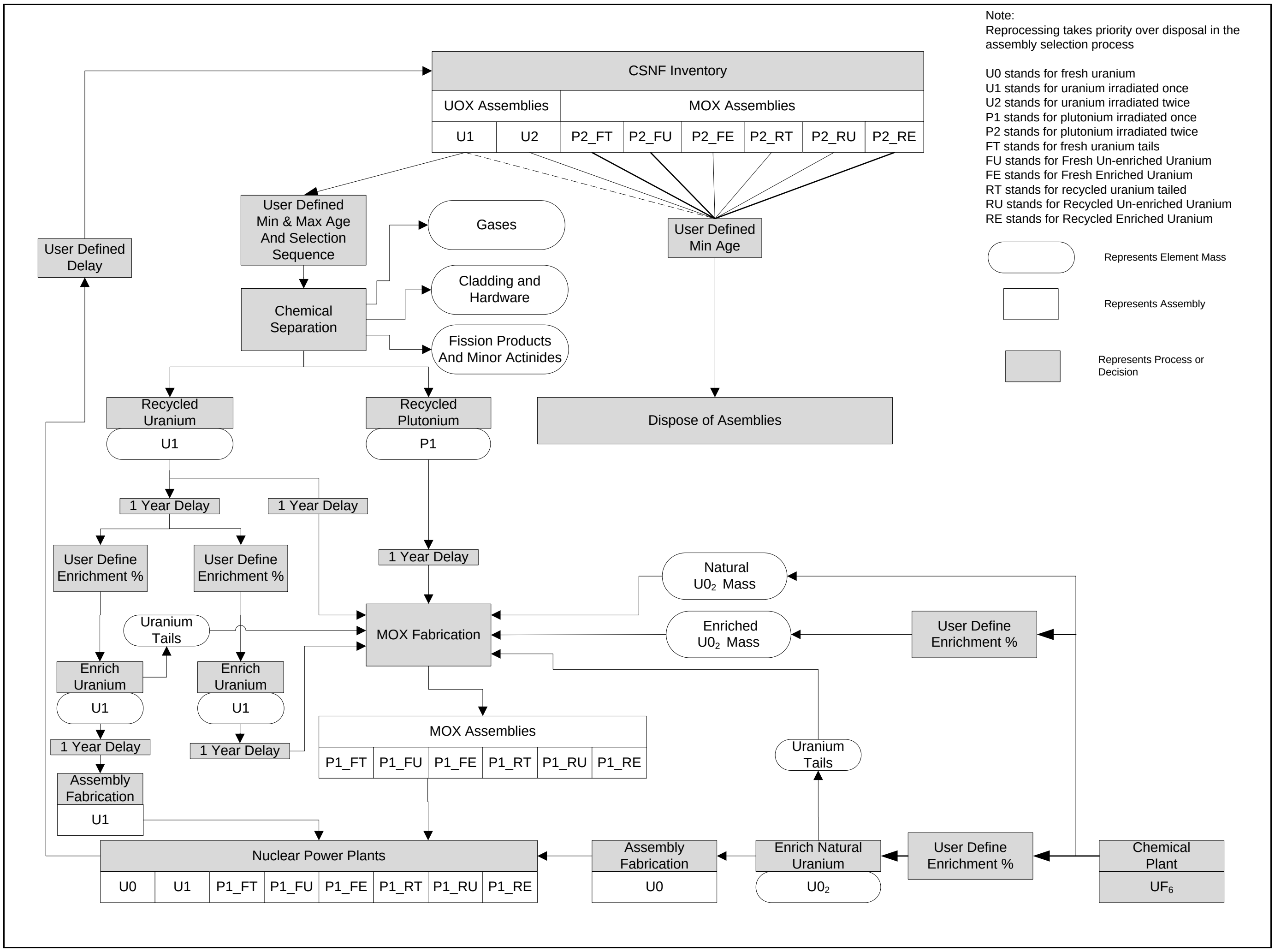

Figure 1 - NUWASTE Functional Flowchart

III. SINGLE SCENARIO EVALUATION

NUWASTE records approximately 85 parameters on a yearly basis and these can be displayed as tabular or graphic reports. Some of the reports show the overall mass and assembly flow through the entire process, while others provide detailed results of numbers and types of assemblies that are reprocessed and disposed, numbers and composition of assemblies fabricated, and masses and types of wastes produced.

Figure 2 shows the mass balance of a hypothetical scenario based on NUWASTE results. This report includes the total number of fuel assemblies that are reprocessed and disposed; the number of first and second cycle UOX assemblies, and the number of MOX assemblies, that are fabricated; and the total mass of waste products, including fresh and recycled tails, solid and gaseous fission products and minor actinides, and low level waste. It also shows the reduction in the number of repository waste packages and the reduction in natural uranium that would result from reprocessing.

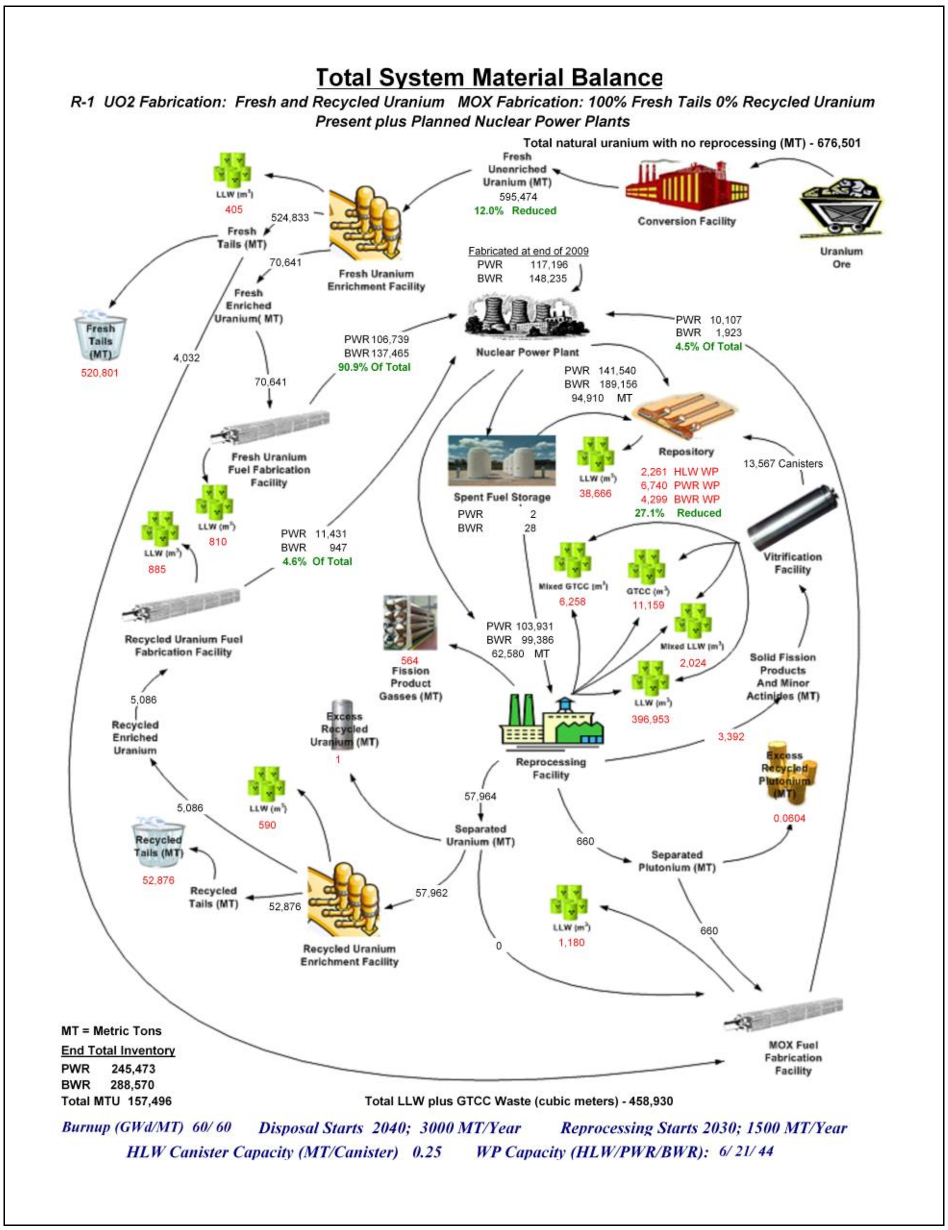

Figure 2 - Total System Material Balance

Figure 3 displays the mass of SNF discharged and the masses of SNF and HLW processed on an annual basis, plus the total number of dry storage casks required and the cumulative mass of SNF discharged.

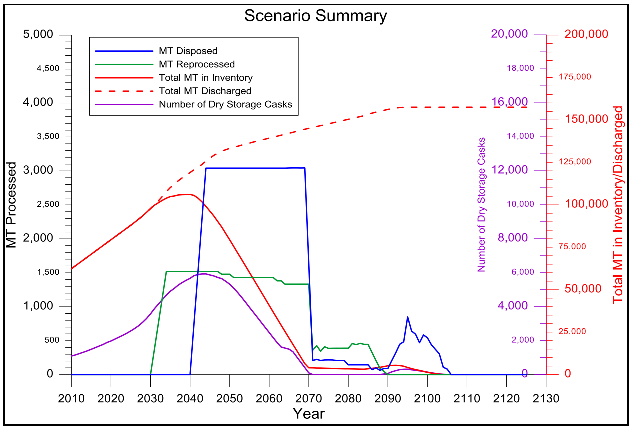

Figure 3 - Scenario Summary

Figures 4, 5 and 6 are examples of the many tabular reports available; the majority of these reports provide results on a yearly basis.

Figure 4 shows the number and mass of assemblies reprocessed each year along with the masses of the major uranium and plutonium isotopes separated. This data is used to calculate the composition of second cycle UOX and first cycle MOX assemblies.

Figure 5 displays the total mass of each waste product isotope separated. Approximately 0.1% of the plutonium and uranium is assumed to be carried over with the other actinides due to incomplete separation. In general, the gases that are released during separation are not carried along with the solids and are not considered in the calculation of the volume of vitrified HLW produced.

Figure 6 shows the number and ^{235}U enrichment of first cycle uranium assemblies fabricated; number and ^{235}U enrichment of second cycle uranium assemblies fabricated; and the number, plutonium percent, plutonium quality, uranium percent, and ^{235}U enrichment of MOX assemblies fabricated. The ^{235}U enrichment of the second cycle UOX assemblies must be increased due to the presence of ^{236}U in the separated uranium mass. The method for calculating the ^{235}U enrichment needed for second cycle UOX assemblies is based on data in the open literature[1] that provides the relationship between the ^{236}U concentration and the ^{235}U enrichment necessary to compensate for the presence of ^{236}U. The calculation method for the MOX assemblies is based on data found in the open literature[2,3] that provides the relationship between plutonium quality and concentration.

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R-1 UO2 Fabrication: Fresh and Recycled Uranium MOX Fabrication: 100% Fresh Tails 0% Recycled Uranium
Present plus Planned Nuclear Power Plants
Disposal Starts 2040; 3000 MT/Year Reprocessing Starts 2030; 1500 MT/year
Burnup PWR/BWR(GWd/MT) 60/ 60 WP Capacity PWR/BWR : 21/ 44

Assembly Reprocessing History

Year	Assemblies			MTU	Uranium Masses					Plutonium Masses					
	BWR	PWR	Total		U234	U235	U236	U238	Total	Pu238	Pu239	Pu240	Pu241	Pu242	Total
2010	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2011	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2012	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2013	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2014	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2015	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2016	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2017	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2018	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2019	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2020	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2021	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2022	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2023	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2024	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2025	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2026	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2027	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2028	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2029	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2030	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0
2031	1,478	288	1,766	375	0.1	1.6	2.5	342.6	346.9	0.15	1.78	1.09	0.39	0.43	3.8
2032	2,956	576	3,532	750	0.1	3.3	5.1	685.2	693.7	0.29	3.57	2.18	0.78	0.85	7.7
2033	4,434	863	5,297	1,125	0.2	4.9	7.6	1,027.5	1,040.2	0.44	5.35	3.26	1.16	1.28	11.5
2034	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.44	1.70	15.2
2035	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.55	1.70	15.3
2036	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.34	1.70	15.1
2037	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.29	1.70	15.1
2038	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.55	1.70	15.3
2039	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.49	1.70	15.3
2040	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.55	1.70	15.3
2041	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.14	1.70	14.9
2042	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.08	1.70	14.8
2043	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.03	1.70	14.8
2044	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	1.00	1.70	14.8
2045	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	0.96	1.70	14.7
2046	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	0.94	1.70	14.7
2047	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	0.91	1.70	14.7
2048	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	0.89	1.70	14.7
2049	5,912	1,151	7,063	1,500	0.3	6.6	10.2	1,370.1	1,387.1	0.58	7.13	4.35	0.86	1.70	14.6

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Figure 4 - Annual Reprocessing History

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R-1 UO2 Fabrication: Fresh and Recycled Uranium MOX Fabrication: 100% Fresh Tails 0% Recycled Uranium
Present plus Planned Nuclear Power Plants
Disposal Starts 2040; 3000 MT/Year Reprocessing Starts 2030; 1500 MT/year
Burnup PWR/BWR(GWd/MT) 60/ 60

Total Mass of FP and Minor Actinides Waste Products by Isotope

Isotope	MT	Isotope	MT	Isotope	MT
*Ag109:	7.7	*Mo97:	82.1	*Sn118:	0.4
Am241:	55.4	*Mo98:	84.1	*Sn119:	0.4
Am243:	17.9	*Nd143:	62.1	*Sn122:	0.5
*Ba138:	133.4	Nd144:	132.0	*Sn124:	0.8
C14:	0.0	*Nd145:	64.4	Sn126:	1.9
*Cd110:	4.8	*Nd146:	75.9	Sr90:	51.9
*Cd111:	2.4	Np237:	44.2	Tc99:	76.4
*Cd112:	1.2	*Pd105:	40.6	Te130:	38.4
*Cd114:	1.3	*Pr141:	110.1	U234:	0.0
*Cd116:	0.5	Pu238:	0.0	U235:	0.3
*Ce140:	128.6	Pu239:	0.3	U236:	0.4
Ce142:	114.3	Pu240:	0.2	U238:	53.3
Ce144:	20.4	Pu241:	0.1	*Xe132:	119.6
Cm245:	0.4	Pu242:	0.1	*Xe134:	156.5
*Cs133:	109.0	*Rb85:	10.0	*Xe136:	235.1
Cs135:	40.7	Rb87:	24.7	*Y89:	44.1
Cs137:	121.5	*Rh103:	37.6	*Zr91:	57.6
H3:	0.0	*Ru101:	78.9	*Zr92:	65.1
I129:	15.2	*Ru102:	83.2	Zr93:	70.9
Kr85:	2.3	*Ru104:	58.0	*Zr94:	78.4
*La139:	123.8	Se79:	0.5	Zr96:	81.7
Mo100:	96.0	*Sn116:	0.3	Other:	0.0
*Mo95:	69.0	*Sn117:	0.4		

Total Gases: 528.7 *Total Solids:* 3,176.4

Grand Total: 3,705.1

Note: Approximately 0.1% of the plutonium and uranium is carried over with the other actidildes during the separation process

** indicates stable isotope*

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Figure 5 – Fission Product and Minor Actinide Wastes

U.S. Nuclear Waste Technical Review Board

R-1 UO2 Fabrication: Fresh and Recycled Uranium MOX Fabrication: 100% Fresh Tails 0% Recycled Uranium
Present plus Planned Nuclear Power Plants
Disposal Starts 2040; 3000 MT/Year Reprocessing Starts 2030; 1500 MT/year
Burnup (GWd/MT) 60 WP Capacity : 21

PWR Assembly Fabrication History

Year	UO2 Assemblies					MOX Assemblies (Fresh Uranium Tails)					Grand Total
	UO		U1		Total	No.	Plutonium		Uranium		
	No.	Enrich	No.	Enrich			%	Q	%	E	
2009	117,196	0.00%	0	0.00%	117,196	0	0.00%	0.00%	0.00%	0.00%	117,196
2010	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2011	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2012	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2013	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2014	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2015	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2016	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2017	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2018	2,610	4.50%	0	0.00%	2,610	0	0.00%	0.00%	0.00%	0.00%	2,610
2019	2,574	4.50%	0	0.00%	2,574	0	0.00%	0.00%	0.00%	0.00%	2,574
2020	2,574	4.50%	0	0.00%	2,574	0	0.00%	0.00%	0.00%	0.00%	2,574
2021	3,685	4.50%	0	0.00%	3,685	0	0.00%	0.00%	0.00%	0.00%	3,685
2022	5,370	4.50%	0	0.00%	5,370	0	0.00%	0.00%	0.00%	0.00%	5,370
2023	3,693	4.50%	0	0.00%	3,693	0	0.00%	0.00%	0.00%	0.00%	3,693
2024	5,069	4.50%	0	0.00%	5,069	0	0.00%	0.00%	0.00%	0.00%	5,069
2025	3,401	4.50%	0	0.00%	3,401	0	0.00%	0.00%	0.00%	0.00%	3,401
2026	3,701	4.50%	0	0.00%	3,701	0	0.00%	0.00%	0.00%	0.00%	3,701
2027	3,375	4.50%	0	0.00%	3,375	0	0.00%	0.00%	0.00%	0.00%	3,375
2028	3,343	4.50%	0	0.00%	3,343	0	0.00%	0.00%	0.00%	0.00%	3,343
2029	3,282	4.50%	0	0.00%	3,282	0	0.00%	0.00%	0.00%	0.00%	3,282
2030	3,036	4.50%	0	0.00%	3,036	0	0.00%	0.00%	0.00%	0.00%	3,036
2031	2,843	4.50%	0	0.00%	2,843	0	0.00%	0.00%	0.00%	0.00%	2,843
2032	2,661	4.50%	49	4.68%	2,710	59	14.68%	56.13%	85.32%	0.20%	2,769
2033	2,371	4.50%	98	4.68%	2,469	119	14.68%	56.13%	85.32%	0.20%	2,588
2034	2,615	4.50%	147	4.68%	2,762	179	14.68%	56.12%	85.32%	0.20%	2,941
2035	2,033	4.50%	196	4.68%	2,229	235	14.84%	55.83%	85.16%	0.20%	2,464
2036	2,030	4.50%	195	4.68%	2,225	239	14.68%	56.12%	85.32%	0.20%	2,464
2037	1,913	4.50%	196	4.68%	2,109	232	14.98%	55.58%	85.02%	0.20%	2,341
2038	1,751	4.50%	196	4.68%	1,947	230	15.04%	55.46%	84.96%	0.20%	2,177
2039	1,656	4.50%	196	4.68%	1,852	239	14.68%	56.12%	85.32%	0.20%	2,091
2040	1,495	4.50%	196	4.68%	1,691	237	14.76%	55.97%	85.24%	0.20%	1,928
2041	1,306	4.50%	196	4.68%	1,502	239	14.68%	56.12%	85.32%	0.20%	1,741
2042	1,184	4.50%	196	4.68%	1,380	225	15.26%	55.07%	84.74%	0.20%	1,605
2043	1,014	4.50%	196	4.68%	1,210	223	15.35%	54.90%	84.65%	0.20%	1,433
2044	790	4.50%	196	4.68%	986	221	15.43%	54.76%	84.57%	0.20%	1,207
2045	742	4.50%	196	4.68%	938	220	15.47%	54.70%	84.53%	0.20%	1,158
2046	698	4.50%	196	4.68%	894	218	15.54%	54.58%	84.46%	0.20%	1,112

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Figure 6 - PWR Yearly Assembly Fabrication History

Figure 7 shows the masses of some other waste products that are calculated by NUWASTE. These include fresh and recycled uranium tails, solid and gaseous fission products, and minor actinides.

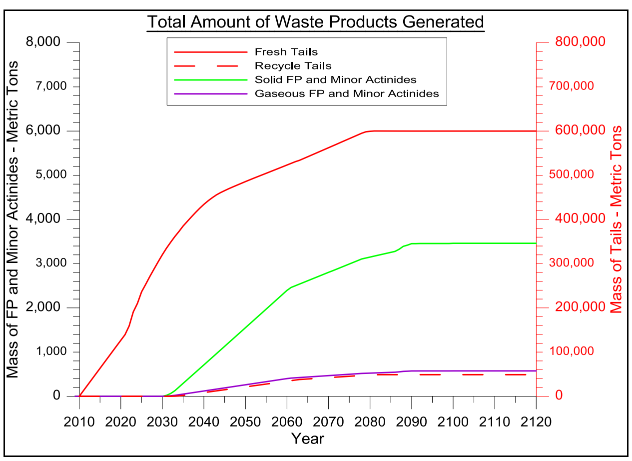

Figure 7 - Waste Products Created

IV. COMPARISON OF MULTIPLE SCENARIOS

NUWASTE has built-in functions that allow comparison of scenarios to determine the sensitivity of particular criteria to changes in the scenario assumptions, such as reprocessing start time and capacity. After each scenario is run, approximately 100 parameters are archived for later evaluation. A report generator is provided within NUWASTE that allows filtering, sorting, and defining those parameters to include in both tabular and graphic reports. The tabular report can display up to 10 different parameters. The graphic reports allow comparison of a single variable for multiple scenarios. For graphic reports, the raw data is normalized to one and a bar graph is generated to display the normalized data, where negative numbers indicate a less desirable choice. Figure 8 shows the bar graph for the "Mass Natural Uranium Used".

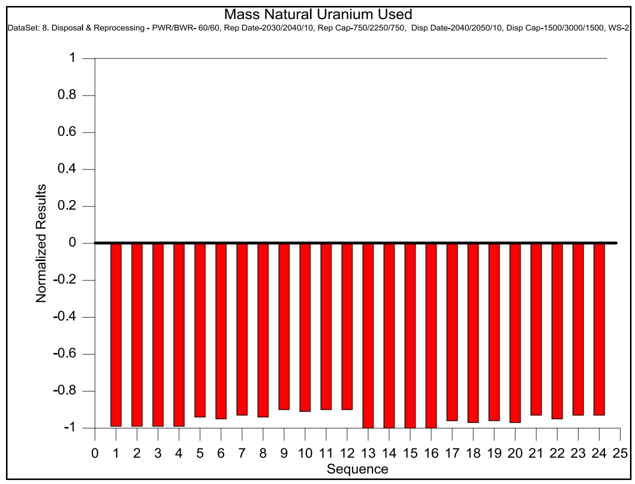

Figure 8 - Example of Normalized Results of a Single Variable

NUWASTE also includes a function that enables evaluation of up to seven criteria at once, selected from a list of approximately 60 criteria. Reported results include minimum, maximum, and average values for each selected criterion. A different weighting factor can be applied to each criterion. NUWASTE normalizes each criterion to one, multiplies the result for each criterion by the appropriate weighting factor, adds the corresponding results, and divides the totals by the sum of the weighting factors. An example of this evaluation is provided in Figure 9.

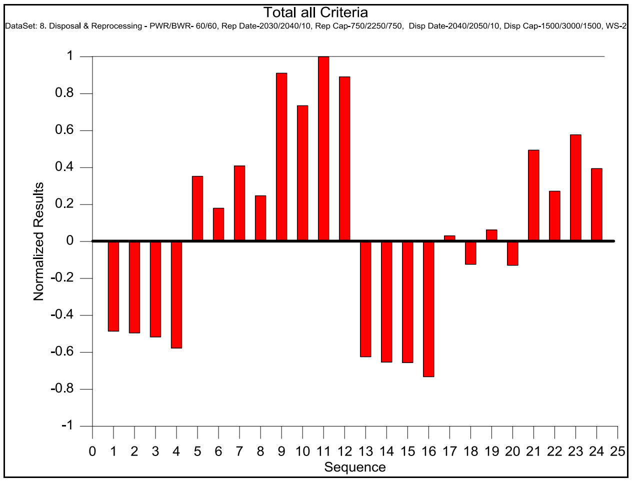

Figure 9 - Example of Multiple Criteria Evaluation

V. SAMPLE EVALUATION

There are numerous combinations of independent variables upon which to base an analysis to investigate the consequences of adopting different SNF and HLW management options for the U.S. LWR fleet for the foreseeable future. In order to illustrate the flow and accumulation of materials, four scenarios based on plausible parameters and capacities have been analyzed using NUWASTE. They are:

1) no repository, no reprocessing, and 60 GWd/MT burnup
2) a repository available in 2040 with an operating capacity of 3,000 MT/year, no reprocessing, and 60 GWd/MT burnup
3) a repository available in 2040 with an operating capacity of 3,000 MT/year, reprocessing available in 2030 with an operating capacity of 1,500 MT/year, and 60 GWd/MT burnup
4) same as 3) but with 40 GWd/MT burnup.

All of these scenarios assume operation of the present reactor fleet plus 28 planned nuclear power plants.

A discussion of pertinent results for these scenarios follows, based on an evaluation of the masses of SNF discharged and in interim storage as a function of time, the peak number of dry storage casks required, and the reduction in demand for natural uranium as a result of reprocessing. Because of the adverse effects of the buildup of even uranium and plutonium isotopes in LWR fuel, MOX and UOX fuel assemblies derived from reprocessed material are burned only once and then stored or disposed.

Scenario 1 is considered the base case for comparison to the other scenarios. As shown in Figure 10, the mass of SNF steadily increases as a function of time, as does the number of dry storage casks required. Figure 11 displays the number of dry storage casks that are required each year. At the end of the century, this totals approximately 13,000, containing 165,000 MTHM of used nuclear fuel. This result is put into perspective by noting that the licensed capacity of the Yucca Mountain repository was expected to be limited to 63,000 MT of commercial SNF.

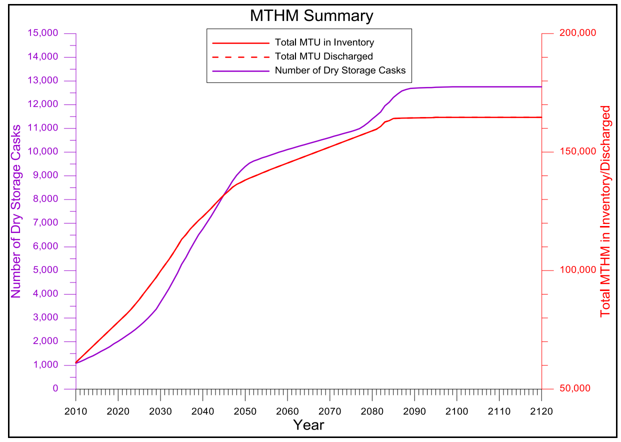

Figure 10 - Scenario 1 - Cumulative Results

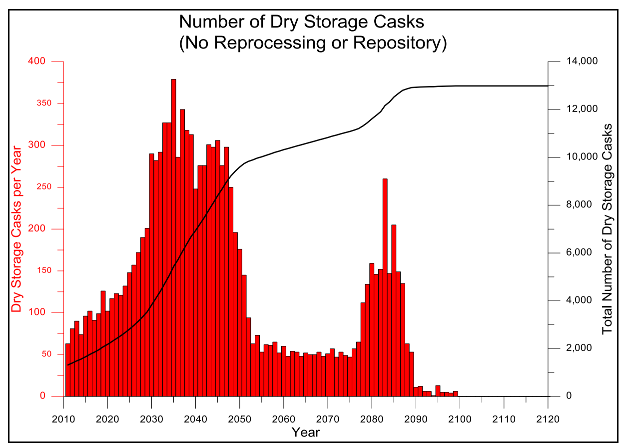

Figure 11 - Scenario 1- Annual Results

Scenario 2 includes a repository starting operations in 2040 with a capacity of 3,000 MT/year. The effect of an operating repository is illustrated by the results for Scenario 2 in Figure 12. This shows that the mass of SNF in storage would peak at 122,000 MT in 2040, and then decrease steadily to zero in 2095. The number of dry storage casks peaks at 7,500, equivalent to 76,500 MT, in 2048. The uranium requirement for this scenario is illustrated in Figure 13, which shows that 750,000 MT of natural uranium would be required.

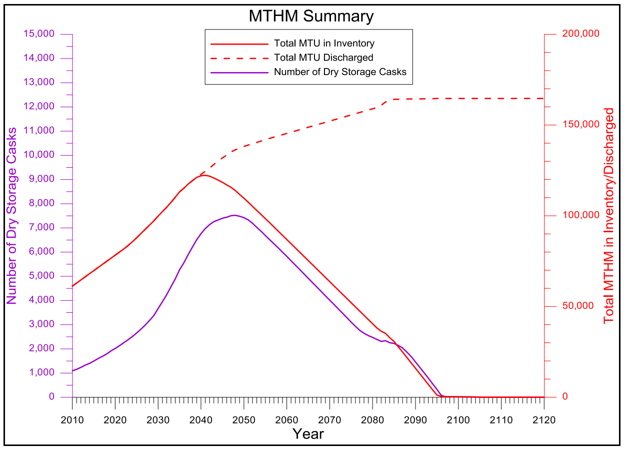

Figure 12 - Scenario 2 - Cumulative Results

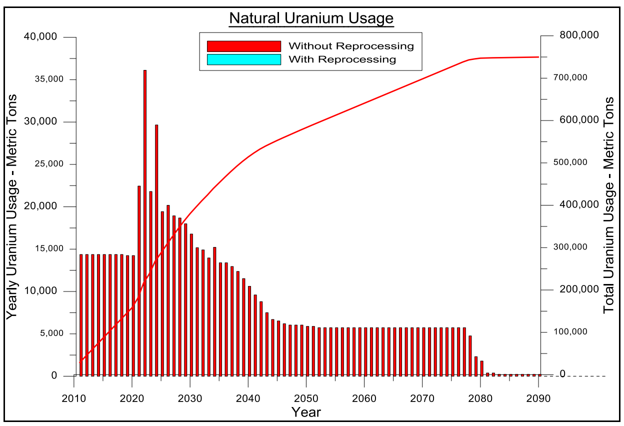

Figure 13 - Scenario 2 - Annual Results

In Scenario 3, reprocessing commences in 2030 with a capacity of 1,500 MT/year. As shown in Figure 14, the number of dry storage casks peaks in 2042 at 5,900 equivalent to 76,500 MT and the mass of SNF in storage peaks in 2039, at approximately 110,000 MT. This is less than the 122,000 MT in Scenario 2 because reprocessing reduces the quantity of SNF requiring storage. The effect of recycling plutonium in MOX fuel, and reprocessed uranium in UOX fuel, can be seen in Figure 15 as a reduction in the demand for natural uranium since the fissile value in these recovered materials is realized as fuel. The reduction in demand for natural uranium is approximately 10%, integrated over time, compared to Scenarios 1 and 2. It is to be emphasized that the size of the reduction is dependent on the timing and capacity of the reprocessing facility, the burnup of the SNF, and the demand for future fuel assemblies.

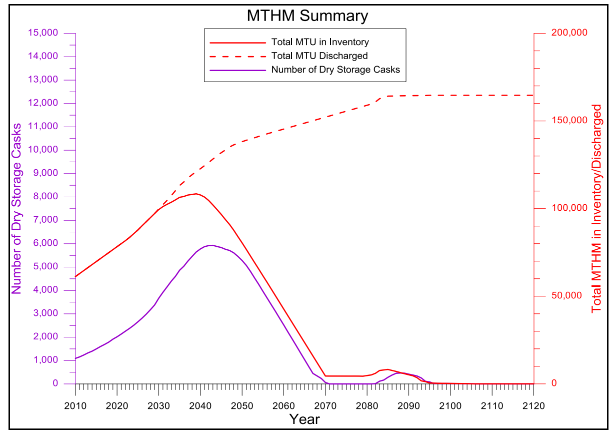

Figure 14 - Scenario 3 - Cumulative Results

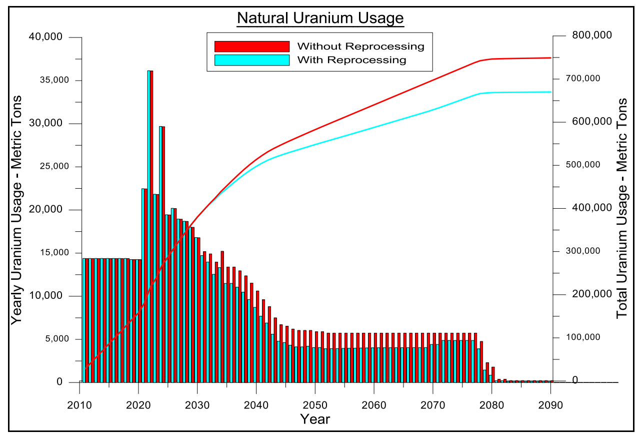

Figure 15 - Scenario 3 – Annual Results

Finally, Scenario 4 shows the effect of limiting burnup to 40 GWd/MT, instead of 60 GWd/MT. The net effect of this lower fuel burnup is illustrated in Figure 16, which shows that the total mass of SNF discharged is approximately 210,000 MT, compared to 165,000 MT in the previous scenarios. As would be expected, discharging fuel with a lower burnup increases the uranium requirement. The number of dry storage casks in this scenario peaks at approximately 8,200 in 2043. The mass of SNF in storage peaks at 140,000 MT in 2039, compared to 109,000 MT in Scenario 3. The reduction in uranium requirement is 14%, as shown in Figure 17. This additional reduction in natural uranium requirement is due to:

1) the higher residual enrichment in the SNF discharged
2) the reduction in even uranium and plutonium isotopes that act as absorbers in recycled fuel

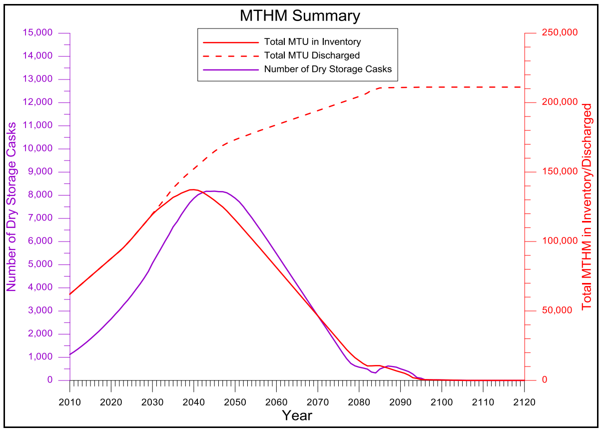

Figure 16 - Scenario 4 - Cumulative Results

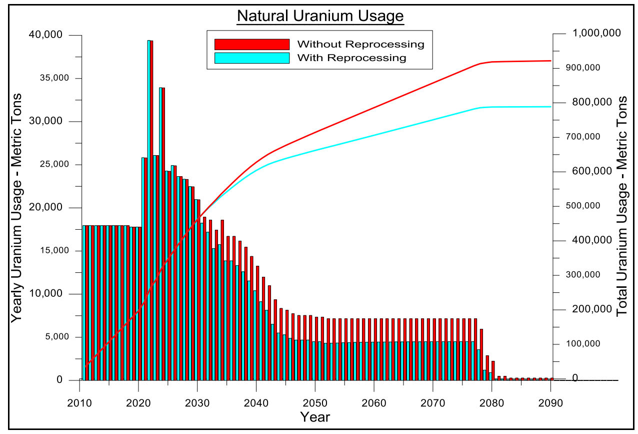

Figure 17 - Scenario 4 - Annual Results

Table I provides a summary of the pertinent scenario results. On the basis of the scenarios evaluated here, it can be seen that:

1) the cumulative mass of SNF would exceed the expected licensed capacity of the Yucca Mountain repository for each scenario
2) repository disposal and reprocessing would reduce the peak quantity of dry storage casks required by over 50%
3) reprocessing would reduce the natural uranium requirement by about 10%
4) reducing the fuel burnup from 60 to 40 GWd/MT would increase the peak quantity of dry storage casks required by about 38% and increase the natural uranium requirement by about 18%.

Table I –Summary of Scenario Results

Scenario	Fuel Burnup PWR/BWR (GWd/MT)	Repository Start Date/ Capacity (MT)	Reprocessing Start Date/ Capacity (MT)	Peak Dry Storage			Natural Uranium	
				Casks	MT	Change (%)	Requirement (MT)	Change (%)
1	60/60	N/A	N/A	12,750	165,000	N/A	750,000	N/A
2	60/60	2040/3,000	N/A	7,500	97,000	-57	750,000	0
3	60/60	2040/3,000	2030/1,500	5,900	76,500	-54	670,000	-10
4	40/40	2040/3,000	2030/1,500	8,200	102,000	+38	790,000	+18

VI. CONCLUSION

NUWASTE offers considerable capability and flexibility in evaluating potential scenarios for managing SNF and HLW in the U.S. The way the system has been designed, makes it possible to evaluate the waste management implications of alternative fuel cycle options, both individually and comparatively. The NWTRB intends to utilize NUWASTE to evaluate plausible options in an effort to better understand and communicate the potential implications for managing SNF and HLW and present the results to interested parties. Future enhancements of NUWASTE are being considered, including adding advanced reactor technologies, disposition of DOE-owned SNF and HLW, and transportation requirements.

VII. REFERENCE

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