RECYCLING ANALYSIS FOR DIFFERENT REACTOR OPERATION SCENARIOS

Gustavo Alonso and J. Ramón Ramírez
Instituto Nacional de Investigaciones Nucleares
Km 36.5 Carretera México-Toluca, Ocoyoacac 52045, Edo. de México, México
galonso@nuclear.inin.mx ; jrrs@nuclear.inin.mx

ABSTRACT

To assess the economical benefits of plutonium recycling we perform an analysis of recycling as a function of the reactor operation cycle. Three different cycle lengths were analyzed, 12, 18 and 24 months. These cycles differ in the average assembly enrichment, the number of fuel assemblies used and the discharge burnup. Thus to have a comparison basis we took the associated cost to produce 1000 kg of UO_2 for each enrichment considered. In each operation cycle two options are considered, direct disposal and recycling of the depleted fuel. The reactor analyzed is a BWR with a thermal power of 1931 MW_e, an efficiency of 34% and a capacity factor of 85%. The analysis shows that the 18-month cycle has the lowest cost of the three scenarios considered because this one has the highest discharge burnup. Furthermore, the cost of the 18-month fuel cycle considering recycling is 5.26 Mills $/KWh, which is only 11% more expensive than the direct disposal.

1. INTRODUCTION

Recycling is a method to reduce the amount of depleted fuel assemblies and to extract the plutonium energy content in them. From an economical point of view it has been considered expensive in comparison with the direct disposal of the depleted fuel assemblies.

Due to the recent operational practices the nuclear energy is in a more competitive status with other ways used to generate electricity. Thus, it will prudent to assess if fuel recycling has also change its status compared with the direct disposal of the depleted fuel assemblies and if it can be considered as an economical option.

Nuclear plants work in different energy cycle lengths, thus the impact on fuel recycling will be different accordingly of the operation cycle. In this work we will analyze three different cycle scenarios.

2. SCENARIOS ANALYZED

Three are the more common time cycles used by the BWR power plants 12, 18 and 24-months. We will analyze a BWR fuel reactor working on these operation cycle lengths. Two options for each operating cycle will be consider: direct disposal and recycling of the depleted fuel assemblies.

The reactor is assumed to be operating in equilibrium cycles for each one of the cycle length analyzed. Under this consideration, each operating cycle will produce different amounts of plutonium because they have different number of fuel assemblies with different average assembly enrichment and these assemblies will have different discharge burnup. Thus to have a comparison basis we will take the associated cost to produce 1000 kg of UO_2 for each enrichment considered The characteristics of the reactor analyzed and the fuel assemblies used in each scenario are given in Tables I and II, respectively.

Table I. Reactor characteristics

Reactor Type	BWR
Thermal Power	1931 MWt
Efficiency	0.34
Weight of core	80.274 MT
Electric power	654 MWe

Table II. Fuel Assemblies characteristics.

Cycle length	12-months	18-months	24-months
Number of assemblies per reload	92	124	148
Average discharge burn up (GWD/TU)	38	43	48
Initial Enrichment (w/o)	3.45	3.66	3.80
Tail Enrichment (w/o)	0.25	0.25	0.25
Conversion losses (%)	0.5	0.5	0.5
Fabrication losses (%)	1.0	1.0	1.0

3. ECONOMIC CONSIDERATIONS

To have an economic comparison basis we will use for all the stages considered in this study the associated costs from the database WISE [2] at December 2000. These costs are shown in Table III. As we mention before, to compare the different cycle lengths scenarios we will calculate the associated cost to produce 1000 kg of UO_2 for each cycle considered. Table IV shows the characteristics of the PuO_2 fuel assemblies that will produce the same energy as the UO_2 fuel assemblies considered in this analysis.

Table III. Associated fuel costs.

Service	**Costs**	**Service**	**Costs**
Preirradiation step		*Postirradiatión step (reprocessing)*	
Natural uranium	25$/kg U_3O_8	Transport of Spent fuel	50 $/kg U
Convertion	2.6 $/kg U		
Enrichment	90 $/kg SWU	Reprocessing	900 $/kg U
Fabrication	275 $/kg U	Waste disposal	610 $/kg U
Postirradiation step (direct disposal)		MOX fabrication	1300 $/kg MP
Transport and interim storage	230 $/kg U	Transport and interim storage	230 $/kg U
Conditioning and final disposal	610 $/kg U	Conditioning and MOX disposal	610 $/kg U

Table IV. PuO_2 fuel assembly characteristics

Cycle length	12 months	18 months	24 months
BWR Fuel assembly	8x8	10x10	10x10
Uranium Enrichment	3.45	3.66	4.10
Fissile Plutonium conc.	5.7%	6.5%	6.94%
Number of cycles before discharge	4	4	3
Burnup Discharge MWD/TU	39500	47384	45230

4. RESULTS

Due to the assemblies considered in this study have different discharge burnups their plutonium vector will be different. To calculate these vectors we used the module ORIGIN of the code SCALE-4 [1]. The result of this calculation is shown in Table V.

For every cycle the two options, direct disposal and recycling, were considered. The associated costs were calculated using the prices of Table III for each cycle stage. The total cost for both options are reported for each cycle considered, these results are reported in Table VI. All economic calculations were made taken as basis 1 ton of UO_2 and then multiplied by the total weight of uranium oxide into the core.

Table V. Plutonium vector

Plutonium Isotope	12-months Discharge Burnup 39,500 MWD/TU	18-months Discharge Burnup 47,384 MWD/TU	24-months Discharge Burnup 45,230 MWD/TU
Pu-238	2.23	2.99	2.74
Pu-239	51.50	47.44	50.46
Pu-240	26.40	26.81	25.47
Pu-241	14.10	14.30	14.30
Pu-242	6.92	8.46	7.03

Table VI. Fuel cycle cost

	12 months		18 months		24 months	
Service	Direct disposition mill$/kWh$_e$	Reprocessing mill$/kWh$_e$	Direct disposition Mill$/kWh$_e$	Reprocessing mill$/kWh$_e$	Direct disposition mill$/kWh$_e$	Reprocessing mill$/kWh$_e$
Front-end	3.0082	2.7201	2.6169	2.3612	2.8034	2.5349
Back-end	2.7195	3.7081	2.2368	3.0500	2.3119	3.1523
Total	5.7277	6.4282	4.8537	5.4112	5.1153	5.6872

From the results shown in Table VI it can be seen that the recycling option goes in a more competitive status as the cycle length operation is increased. However, due to the discharge burnup is not the optimum in each cycle we can see that in the 24-month cycle the cost of recycling option is increased in comparison with the 18-month cycle.

CONCLUSIONS

The analysis shows that the 18-month cycle has the lowest cost of the three scenarios considered, one of the reasons for this result is the fuel assembly utilization. Being the fuel assembly of this option the one with the highest discharge burnup. Furthermore, the cost of the 18-month fuel cycle considering recycling is 5.26 Mills $/KWh, which is only 11% more expensive than the direct disposal option of this cycle.

On the other hand, for the three scenarios considered, from an economical point of view, the recycling option is in a more competitive status because it is less than 15% more expensive than the direct option, and it costs less than 6.5 Mills $/KWh.

Finally, to have a more extended comparison basis, a future work will be to perform a detailed analysis of each cycle considering the electricity produced instead to take a fix amount of UO_2. This type of analysis will allow us to have a comparison based on electricity production.

References

1. S. M Bowman, L. C. Leal, "ORIGEN-ARP, Automatic rapid process for spent fuel depletion, decay and source term analysis", *ORNL/NUREG/CSD-2/VI/RG*, March-2000.
2. *World Information Service on Energy*, Peter Diehl, Germany 2001.