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Cost Comparison of Direct Disposal vs. Pyro-processing and DUPIC in Korea

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1. Introduction

There are 20 nuclear reactors operating in Korea and 4 more are under construction. The spent nuclear fuel and radioactive wastes will be accumulated and an effective management must be introduced as soon as possible. In Korea, pyro-processing and DUPIC (Direct Use of spent PWR fuel In CANDU) are drawing attentions of many researchers and policy makers. However, cost comparison studies of each or both options against the direct disposal have not been adequately conducted. Therefore, the purpose of this study is to compare the fuel cycle strategy in cost terms. Based on mass balance of the Heavy Metal, cost of each process in the fuel cycle was considered. The process cost was divided into sub-categories and each component cost was also assigned. It was found that the pyro-processing-only cannot win against the direct disposal, but it can be compensated by adding DUPIC. Pyro-processing plus DUPIC was cheaper by M$565 than the direct disposal.

2. Cost Comparison Model

2.1 Back-end Fuel Cycle

The fuel cycle strategy in this study is described in Fig. 1 and the assumptions are as follows. (1) one SFR built, which is KALIMER-600, (2) 4 CANDU without capital cost consideration, (3) all SFR fuels are recycled, and (4) all DUPIC fuels are disposed.

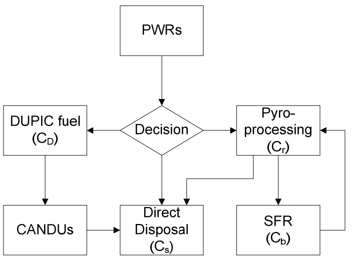

Fig. 1 Back-end fuel cycle options (Pyro-processing and DUPIC)

2.2 Mass Balance

Based on mass balance of Heavy Metal, the following equation can be set. This includes the cost of all three options, direct disposal, pyro-processing, and DUPIC.

$$C_s\left(M_0+\int_0^t \frac{dM_s}{dt}dt-\int_0^t \frac{dM_r}{dt}dt+\int_0^t \frac{dM_w}{dt}dt+\int_0^t \frac{dM_D}{dt}dt\right)+ C_r\int_0^t \frac{dM_r}{dt}dt+C_D\int_0^t \frac{dM_D}{dt}dt+C_b\int_0^t \frac{dM_r}{dt}dt- C_e\left(F_{SFR}\int_0^t \frac{dM_r}{dt}dt+F_{CANDU}\int_0^t \frac{dM_D}{dt}dt\right) \quad (1)$$

where

C_s	is the cost of storage
M_0	is the initial amount of waste
M_s	is the additional amount that must be stored
M_r	is the amount of pyro-processed waste
M_w	is the amount of waste from pyro-processing
C_r	is the pyro-processing cost
C_b	is the burning cost
C_e	is the electricity generation
F	is the conversion factor, or burn-up
M_D	is the amount of DUPIC fuel
C_D	is the DUPIC fuel fabrication cost
F_x	is the conversion factor, or burn-up of x reactor

2.3 Comparison Model

If we assume that,

$$\int_0^t \frac{dM_i}{dt}dt=k_i \quad (2)$$

Comparison between the options will be,

$$C_s\left(M_0+k_s\right) \text{ vs.} \quad (3)$$

$$C_s\left(M_0+k_s-k_r+Ak_r+k_D\right)+C_rk_r+C_Dk_D+C_b-C_e\left(F_{SFR}k_r+F_{CANDU}k_D\right)$$

With the rearrangement and putting equal on both sides then the eq. (3) is,

$$0=k_r\left[\left(A-1\right)C_s+C_r-C_eF_{SFR}\right]+k_D\left(C_s+C_D-C_eF_{CANDU}\right)+C_b \quad (4)$$

2.3 Cost Information

The values for the costs in eq. (4) are shown in Table 1. The storage cost includes the cost of interim storage and the cost of geological disposal. Pyro-processing cost includes the cost of processing itself and the cost of metal fuel fabrication. The burning cost includes the capital cost and O&M cost of SFR. The compensation cost of electricity compensation includes the domestic electricity price. The DUPIC fuel fabrication cost includes the capital cost and O&M cost of the facility. Conversion factor (burn-up) is the data from KALIMER-600 and CANDU reactors in Wolsong.

Table 1 Values for the cost variables

	Value	Remark
C_{is}	\$800/kgHM	INL-AFC Cost Basis Report
C_{ds}	\$900/kgHM	INL-AFC Cost Basis Report
C_{pp}	\$2700/kgHM	INL-AFC Cost Basis Report, 500 MTHM/yr
C_{fab}	\$5000/kgHM	Controversial (Y. Chang estimates \$1100), but little effect
CP_{SFR}	\$2300/kWe	Estimated capital cost from the conventional PWR capital cost
CO_{SFR}	\$68/kWe	Assumed to be similar to that of LWRs
P	\$0.089/kWhr	Domestic electricity price
CA	600MWe	KALIMER-600
A	0.024	Pyro-process simulation
k_r	3737.4 kg-Pu	Fissile Pu inventory of KALIMER-600
F_{SFR}	31.2 MWd-e/kg	KALIMER-600 average burn-up, efficiency = 39%
C_D	\$616/kgHE	H. Choi et al(2001), 400 tones HE/yr
k_D	241168 kg	DUPIC fuel data for 4 reactors, one CANDU can take 282 channel x 12 bundle x 17.8 kg/bundle
F_{CANDU}	4.5 MWd-e/kg	Burn-up of DUPIC fuel, efficiency of CANDU = 30%

3. Results

Direct disposal is cheaper than pyro-processing-only by \$1.2 billion in total cost. One of the reasons that may have influenced is that the capacity of SFR was set to be rather small. The commercial size of SFR is expected to be about 1400 MWe or larger, whereas the capacity of KALIMER is only 600 MWe. When it comes to the construction of an actual reactor, the capacity will be increased and also, it may not be just one. The larger the capacity is, the more economical the reactor is.

Direct disposal is more expensive than pyro-processing + DUPIC by \$565 million. Unlike SFR, CANDU reactors are already built in Korea and so the effect of capital cost was minimized. Furthermore, the spent nuclear fuel does not have to undergo any reprocess, but only re-fabrication to be used as DUPIC fuel. This is where the DUPIC earns its highly economical aspect.

4. Conclusions

Although there have been many studies regarding the cost of nuclear spent fuel management, cost comparison between the direct disposal and the pyro-processing with DUPIC has hardly drawn the interests since there exists no countries capable of taking both pyro-processing and DUPIC strategy. Korea, with the special condition of being able to pursue both ways, necessitates an economical analysis to decide the back-end fuel cycle scheme and we provide such an economical basis in this study. The primary conclusion of this study is that the pyro-processing alone is still more costly than the direct disposal, but it can be compensated by the DUPIC at a feasible range. Most of the cost data used in this study is based on domestic situation and the rest are independent. It is recommended that further studies should be done with the commercial-size design of SFR and on other important areas such as safety, security, etc.

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