Economic and Environmental Value of Advanced Fuel Cycle

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1. Introduction

The Advanced Fuel Cycle (AFC) includes the pyro-processing technology coupled with SFR system. The goal of AFC is to achieve a significant reduction of High Level Waste (HLW) and accumulated plutonium in the SNF through Partitioning and Transmutation (P&T), and to recover the useful materials from the SNF. Because of its technological advantages in many aspects, its possibility of realization was tested and supported by many studies and works. The economic value of AFC has been the main concern since its development, albeit the bigger merit in other aspects. In this study, therefore, other value, namely the environmental value will be discussed and the sum will be also considered.

2. Economic Value

Simple economic value comparison in total fuel cycle is shown in Table 1. The SFR-Pyro cycle of AFC assumes that its fuel is totally supplied from LWR SNFs and the pyro-processing of oxide fuels is done only one time which provides lifelong fuel supply for SFR. The pyro-processing of metal fuel is conducted many times to recycle the uranium and actinides. As can be seen, the cost composition for the AFC is much higher than that of direct disposal. Especially, the capital cost of SFR is crucial due to its influence on total cost ($5,000/kWe × 1 GWe ~ $5B). However the cost estimate for SFR is controversial and it may unveil to be lower or higher than the expectations in future.

Current nuclear power cost ratio (capital cost : fuel cost : O&M cost) is 70:23:7 corresponding to 2, 0.65, 0.2 cents/kWh, respectively. Among 23 of fuel cost, 3 is saved as a fund for nuclear waste management (0.1 cents/kWh). If we consider without the O&M cost, we can modify the ratio to capital : uranium : waste, which is 75:22:3. The fund for waste management per one LWR is then about $350 million assuming the 40 years of plant life. However, the actual cost is estimated to go over this fund in great manner. The total back-end fuel cycle cost will be around $1,200/kg including interim storage and repository cost. Therefore it is estimated that the waste management cost will be about 3 times more than current portion of busbar cost and the value is shown in Table 2.

On the other hand, the power cost for recycling including SFR and pyro-processing can also be calculated with several assumptions. (1) SFR capital cost: 1.5 of LWR capital cost, (2) Pyro-processing and waste disposal according to the mass flow of IFR system (Fig. 1), (3) Plant life: 40 years. The power cost value is shown in Table 2.

It can be summarized that the AFC cannot win against the direct disposal with the current economic value. All of the cycle – namely, front end, power plants, and back end – costs for AFC are higher than direct disposal option.

Table 1 Simple cost comparison

Front end				***NPP***	***Back end***	
U_3O_8	Conversion	Enrichment	Fabrication	LWR	Interim	Repository
$80/kg	$10/kg	$115/SWU	$264/kg	~$3,000 /kWe	$300/kg	$900/kg
Recycling & Fabrication				SFR	Pyro (one time)	
~$2,700/kgHM				~$5,000 /kWe	~$1,500/kg	HLW

Table 2 Power cost comparison

	Capital	***Fuel***	***O&M***	***Cycle***
Cost (c/kWh)	2	0.88	0.2	Once-through
Ratio (%)	65	29	6	
Cost (c/kWh)	3	0.704	0.2	Recycling
Ratio (%)	77	18	5	

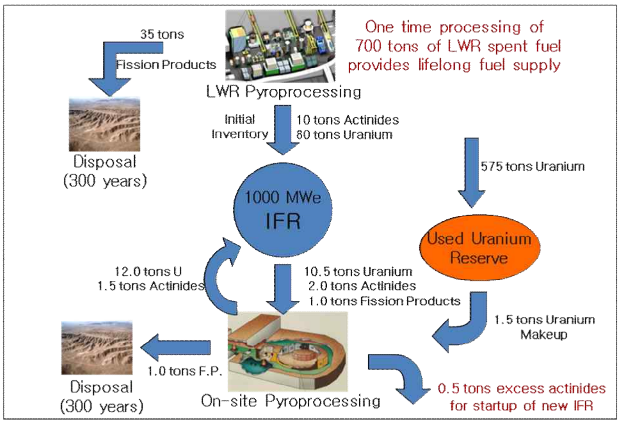

Fig. 1 Fuel supply and flow for IFR system

3. Environmental Value

The idea of retrieving the uranium by pyro-processing and transmutating the TRU in SFR necessarily reduces the amount of SNF accumulation. Furthermore, the fuels for SFR are supplied from SNF in AFC. This means that SFR is not in need of uranium and hence no spending on purchasing the U_3O_8. The front end cost for AFC is theoretically zero. 2 points above can be described in the power cost term, and they are as follows.

- *SNF reduction*: In Korea, the accumulated SNF is now 9,300 tons and 700 tons are discharged yearly. Existing waste cost is not included in the power cost calculation. The waste cost per one LWR (0.1 cents/kWh) is for the future waste of LWR of consideration. AFC can reduce the accumulated SNF. For example, the interim storage for 9,300 tons of waste is ~$2.7B. If 5 SFRs are built, the corresponding pyro-processing can reduce 3,500 tons. Therefore the storage cost drops to ~$1.74B. This is the same meaning of – 0.06 cents/kWh. The more the SFR is built the less the waste accumulates. If the waste amount is over the limit of interim storage then the cost should be changed to – 0.2 cents/kWh to incorporate the final disposal at geologic repository.
- *Uranium utilization*: The fuel cost of 0.65 cents/kWh corresponds to the uranium price of ~$120/kg. However if the identified uranium of 6.3 million tons are all used and hence the price goes over, the uranium cost becomes 0.86 cents/kWh. Adding the waste management cost will make $1.19 cents/kWh in total.

It can be summarized that the environmental value of AFC was verified to be enough to compensate the additional spending on building and setting up new systems.

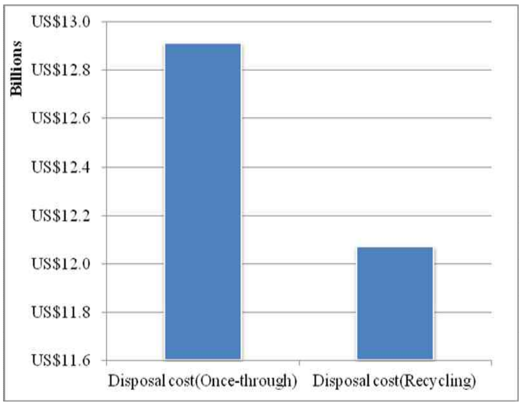

Fig. 2 Disposal cost comparison of each option

4. Total Value

With the assumptions used in previous section, the power cost can be calculated roughly by the following equation.

$$TotalCost = (3.08R_{LWR} + 3.9R_{SFR}) + \begin{cases} -0.06R_{SFR}(if, x \le i) \\ -0.2R_{SFR}(if, x > i) \end{cases} \quad (1)$$

where, R_t is the ratio of t reactor to total number of plants(SFR+LWR), and x is the cumulative amount of SNF, and i is the maximum interim storage capacity.

The first bracket term is the economic value and the second is the environmental value. The choice in second term is the cost saving for SNF reduction at the disposal cost of interim storage and final disposal. The amount of leftovers from already accumulated SNF minus recycling will decide the cost value of – 0.06 or – 0.2.

5. Conclusion

The economic and environmental value of SFR and pyro-processing technology included in Advanced Fuel Cycle has been investigated throughout this study. The economic value for the AFC alone cannot win against the direct disposal due to the high cost for Sodium-cooled Fast Reactor construction and pyro-processing facility. However, in environmental value, significant merits over direct disposal were achieved by reduced accumulation of the SNFs and less purchased uranium for reactor fuel. It can be concluded that the total value of the AFC can be greater than that of direct disposal, if the required condition is set. For further extension of this study, consideration of safeguard and social value for each cycle will provide important information.

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