Economic Analysis of Pyro-SFR Fuel Cycle

Fanxing Gao, Byung Heung Park, Eun-ha Kwon, Won Il Ko
Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, Korea, 305-353
gao@kaeri.re.kr

1. Introduction

SFR fuel cycle employing pyroprocessing (named as Pyro-SFR Cycle) is one promising fuel cycle option in the near future. Economics is one of the essential criteria to be considered in the determination of new fuel cycle deployment. In this study, based on the material flow the economics of Pyro-SFR has been estimated. There are mainly two methodologies to perform nuclear fuel cycle cost study which is based on the material flow calculations. One is equilibrium model and the other is dynamic model. Equilibrium model focus on the batch study with the assumptions that the whole system is in a steady state and mass flow as well as the electricity production all through the fuel cycle is in equilibrium state, which calculates the electricity production within a certain period and associated material flow with reference to unit cost in order to obtain the cost of electricity. Dynamic model takes the time factor into consideration to simulate the actual cases. Compared with the dynamic analysis model, the outcome of equilibrium model is more theoretical which may offer relatively clear and direct comparisons, especially with regard to the large uncertainty of the development of the pyro-technology evaluated. In this study equilibrium model was built to calculate the material flow on a batch basis. With the unit cost being determined, the cost of each step of fuel cycle could be obtained, so does the FCC[1-3].Due to the unavoidable uncertainty with certain unit costs, evaluated cost range and uncertainty study are applied. Sensitivity analysis has also been performed to obtain the breakeven uranium price for Pyro-SFR against PWR-OT[4,5].

2. Method

2.1 Main components of nuclear fuel cycle

The breakdown structure of the nuclear fuel cycle scheme is specified by the series of components (or steps) included in the four fuel cycle options of this study, shown in Fig.1. Material flow data is also specified in Fig.1.

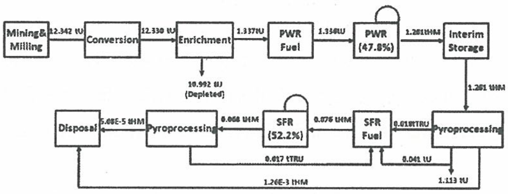

Fig. 1. Main components in the nuclear fuel cycle

2.2 Unit Cost Specification

For fair comparison the cost data in this paper is presented in current-year (2010) dollars. Cost data that were incurred or reported at different times were converted into 2010 dollars using an escalation rate of 3%. Main source of the unit cost data in this study is from OECD/NEA study and Advanced Fuel Cycle Cost Basis, and engineering judgments were used when such data was not available.

2.3 Lead and Lag Time

Lead and lag time are considered, as listed in Table 1.

Table 1. Lead and Lag time of fuel cycle steps

	FC process	Time (month)
Lead time (month)	Purchase	21
	Conversion	18
	Enrichment	12
	Fabrication	6
Lag time (month)	Interim Storage	18
	Reprocessing	78
	Final Disposal	480

3. Results and discussion

3.1 Levelized Cost of Electricity

The calculation results of assessing the fuel cycle scenarios, based on the unit costs, show Pyro-SFR is 7.68 mills/kWh, 19 % higher than the Direct Disposal option, respectively.

Uranium price is the key cost component. With the current uranium price, the LFCC gap between Pyro-SFR and PWR-OT is not big. Pyroprocessing and metal fuel fabrication cost take a big part of the cost.

3.2 Uncertainty analysis

The results from Monte Carlo simulation are shown in Table 2. With the assumption that each of the unit cost is triangular distribution, a total of 50,000 extractions of Latin Hypercuve were performed. The standard deviation (SD) for the fuel cycle costs is 1.19 mills/kWh as shown in Table 2.

Table 2. Results of the Monte Carlo Simulation for the Uncertainty Analysis of Fuel Cycle Costs

Min	Max	Mean	SD
4.65	13.21	8.71	1.19

3.3 Sensitivity Analysis

Sensitivity analysis was conducted on key cost components as uranium price, elector-refining process, metal fuel fabrication, etc. in Fig. 2. The highest sensitivity was shown by uranium price. It was determined that the regression coefficient of uranium ranged 0.85. The Pyro-SFR shows higher sensitivities with pyroprocessing of PWR spent fuel and SFR metal fuel fabrication employing by pyroprocessing.

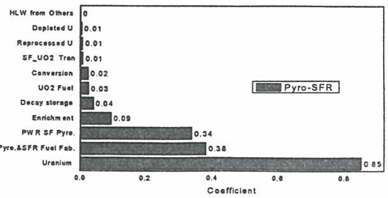

Fig. 2. Sensitivity coefficient of nuclear fuel cycle components

4. Conclusion

Economics of Pyro-SFR fuel cycle scenario has been calculated and compared by employing equilibrium model. The LFCC were obtained, Pyro-SFR 7.68 mills/kWh. The Uranium price is the dominant driver of LFCC. Pyro-techniques also weight considerably in Pyro-SFR scenario. On consideration of the current unavoidable uncertainties introduced by certain cost data, cost range and triangle techniques were used to perform the uncertainty study which indicates that the gap between Pyro-SFR and PWR-OT fuel cycle scenario is relatively small.

5. Reference

[1] W. I. Ko, H. B. Choi and M. S. Yang, "Economic Analysis on Direct of Spent Pressurized Water Reactor Fuel in CANDU Reactors(IV) - DUPIC Fuel Cycle Cost", Nuclear Technology, Vol. 134, May 2001.

[2] OECD/NEA, Advanced Nuclear Fuel Cycles and Radioactive Waste Management, 2006.
NEA(2002), Accelerator-driven Systems(ADS) and fast reactors (FR) in Advanced Nuclear Fuel Cycles, OECD, Paris.

[3] OECD/NEA, 2006, Advanced Nuclear Fuel Cycles and Radioactive Waste Management, NEA No. 5990, OECD 2006.

[4] Shropshire, D., et al., 2008, "2008 Advanced Fuel Cycle Cost Basis," INL/EXT-07-12107 Rev.1, March 2008.

[5] D.E. Shropshire, K.A. Williams, W. B. Boore, et. al., Advanced fuel cycle cost basis. INL/EXT-07-12107 Rev.1.