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Key Factor Analysis of Recycling Fuel Cycle using Scenario Planning

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1. Introduction

Recycling fuel cycle includes the burner-type fast reactor and reprocessing of the Spent Nuclear Fuel (SNF). In Korea, combination of Sodium-cooled Fast Reactor (SFR) and pyro-processing is considered as one of the future nuclear fuel cycle strategy. The objective of this study is to identify and to see the effect of the key factors. Scenario planning was used to analyze the key factors of introducing recycling fuel cycle and various scenarios are presented.

2. Scenario Planning

2.1 Identification of driving factor

The main issue is whether to go or not for recycling fuel cycle and one of the major decision-making elements is the economics. Recycling economics is highly dependent of costs occurring due to the introduction of new systems and processes, such as SFR and pyro-processing. Through sensitivity analysis of Linear Programming method [1], the key driving factor was found out to be the direct disposal cost (geologic repository), the recycling system cost (SFR and pyro-processing facility), and the uranium price.

2.2 Scenario selection

The probable scenarios are shown in Fig. 1 and three cases are selected (the numbered scenarios in Fig. 1). The selection criteria are as follows. The uranium price is very unlikely to go down in future and hence such scenarios are omitted. Also the scenarios with clear decision-makeable cases are omitted, such as disposal cost up – recycle cost down – uranium price up scenario. In this case, it is clear that recycling is the best choice. Same logic can be applied to the opposite scenario (disposal down – recycle up – uranium down) and direct disposal will be the first pick.

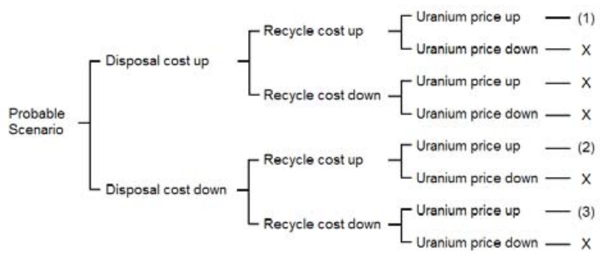

Fig. 1 Probable scenarios and selection

3. Result

Linear Programming (LP) optimization method was used to assess the selected scenarios.

3.1 Cost information

Direct disposal cost mainly consists of geologic repository cost including the facility capital cost, monitoring and handling cost, transportation and etc. The cost data from Yucca Mt. (US) and Olkiluoto (Finland) experiences is shown in Table I.

Recycling cost must be considered in two systems, which are SFR and pyro-processing facility. The estimated costs for each system are shown in Table I.

Uranium price projection by the OECD-NEA is described in Table I.

The projected range (lowest to highest) for each costs are shown in Table II.

Table I: Cost data from various sources

Disposal cost	Yucca Mt.	$921,600/MTHM
	Olkiluoto	$756,363/tU
Recycling cost	SFR	$3000/kWe + α
	Pyro-processing	$840/kgHM (metal fuel) $142/kgHM (oxide fuel)
Uranium price	Identified (6.3Mt)	$80/kg
	Undiscovered (16.7 Mt)	$260/kg
	Unlimited	$520/kg

Table II: Cost range from lowest to highest

Disposal cost	Interim storage ($/kgHM)	2 ~ 20
	Geologic repository ($/kgHM)	20 ~950
Recycling cost	SFR capital cost ($/kWe)	3000 ~ 4000
	Pyro-processing cost ($/kgHM)	500 ~ 5000
Uranium price	Identified ($/kg)	80 ~ 120
	Undiscovered ($/kg)	260 ~ 350
	Unlimited ($/kg)	520 ~ 750

3.2 Result

The sensitivity analysis results are as follows. In the case of scenario (1), the results showed that the optimum SFR introduction year is 2021 and pyro-processing facility must be fully operated at its maximum capacity to supply SFR fuels while reducing the SNF at the same time. Because of the high cost for final disposal (geologic repository), the SNF is kept under the level of interim storage capacity until 2070 by when the pyro-processing capacity increases unlimitedly. Whereas, scenario (2) clearly indicated that the recycling fuel cycle is more costly and thus it is better to go for direct disposal. Unless the uranium prices rise up to $150, $600, and $1200 for the respective conditions, SFR and pyro-processing is not a good idea. For scenario (3), the optimum SFR introduction year was 2034 and pyro-processing facility was operated at full capacity, same as scenario (1). Interesting result is that the pyro-processed SNFs were not fully used and stayed as stock fuels since there are not enough SFRs to consume.

Among 3 factors, recycling cost turned out to be the most dependent driving factor. Small change (both increase and decrease) influenced many results including optimum introduction year, total system cost, amount of SNFs, optimum amount pyro-processed SFR fuels, and etc. Furthermore, the projected cost range for the SFR and pyro-processing was the biggest. On the other hand, the uranium price made the least effect to the system. The distinguishable result changes started to appear when the price change was almost 50% of its starting point. It could be more meaningful if the scale of the study extends to the world energy situation that the amount of uranium purchased will be in different order of number compared to the domestic case.

3.3 Discussion

In the base of all scenarios, future energy demand is assumed. The LP optimization was conducted to fulfill the lowest total system cost. However, changes in energy demand assumption can result in quite big difference because the build-up ratio strongly depends on the energy demand curve. In this study, general assumption from “Nuclear Century Outlook” of World Nuclear Association (WNA) was used to avoid arbitrary result. Although many assumptions are used besides the energy demand, the study tried to be neutral for all data.

4. Conclusion

Recycling fuel cycle is a tempting option for Korea, but there is no strong evidence that it is beneficial. Using well-known scenario planning method with LP optimization, the key factors were analyzed; Direct disposal (geologic repository) cost, recycling (SFR + pyro-processing) cost, and uranium (U_3O_8) price. Among 3 factors, the recycling cost turned out to be the most influencing factor, whereas the uranium price was the least. For further extension of this study, more concrete and practical database of the costs will be useful.

REFERENCES

[1] Lee, J. et al., Linear Programming Optimization of Nuclear Energy Strategy with Sodium-cooled Fast Reactors, Nuclear Engineering Technology, Vol. 43, p. 383, 2011.
[2] R.W. Hardie et al., ALPS, A Linear Programming System for Forecasting Optimum Power Growth Patterns, HEDL-THE-72-31, 1972.
[3] Chang, Y.I. and Till, C.E., Economic Prospect of the Integral Fast Reactor Fuel Cycle, Intl. Conf. on Fast Reactors and Related Fuel Cycles, Vol. II, pp 18.6-1 ~ 18.6-6, 1991.
[4] Bunn, M. et al., The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel, Harvard Univ., 2003.
[5] Forty Years of Uranium Resources, Production and Demand in Perspective, The Red Book Retrospective, OECD Nuclear Energy Agency, 2006.