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Uranium Resource Availability Analysis of Four Nuclear Fuel Cycle Options

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1. Introduction

The theory that nuclear energy is the most competitive energy sources in terms of sustainable energy supply is beyond question; however, there are a few existing problems whenever ‘nuclear energy’ is discussed among the public. The problems being mainly discussed placed an emphasis on the more comprehensive aspects of it. That is, firstly, how to use limited uranium resources efficiently? Secondly, is that possible to dispose of used fuel environmentally safely? Thirdly, how to deal with nuclear nonproliferation? Fourth, is nuclear energy economically feasible compared to other energy resources? Fifth, is nuclear energy possible to be technically developed? [1]

That is to say, making the national policy regarding nuclear fuel cycle option, the policy should be established in ways that nuclear power generation can be maintained through the evaluation on the basis of the following aspects. To establish the national policy regarding nuclear fuel cycle option, that must begin with identification of a fuel cycle option that can be best suited for the country, and the evaluation work for that should be proceeded.

Like all the policy decision, however, a certain nuclear fuel cycle option cannot be superior in all aspects of sustainability, environment-friendliness, proliferation-resistance, economics, technologies, which make the comparison of the fuel cycle options very complicated. For such a purpose, this paper set up four different fuel cycle of nuclear power generation considering 2nd Comprehensive Nuclear Energy Promotion Plan(CNEPP), and analyzed material flow and features in steady state of all four of the fuel cycle options.

2. Fuel Cycle Option

2.1 Types of four different fuel cycle option

Among the types of NPP generating power currently for commercial operation worldwide, LWR accounts for the largest part of the NPP. By accounting from 2009, the number of NPP has been operating in the OECD countries for commercial operation is total 340; 301 LWR, 21 HWR, 18 Gas Cooled Reactor(GCR) have been operating. Likewise, it is appropriate that fuel cycle option is analyzed focusing on LWR for the reason why the LWR accounts for the largest number of the nuclear reactors.

National NPPs are composed of 18 PWR and 54 CANDU reactors, total 23 reactors are being operated to generate power in Republic of Korea. The options of fuel cycle analyzed in this paper were focused on PLWR, taking following four different fuel cycle options that are likely adopted by ROK.

-Once-through Cycle (OT cycle)
-DUPIC Recycle
-Thermal Reactor Recycle
-Pyro-SFR Recycle

2.2 Fuel Cycle Option Scenario

All the scenarios make strong contrast with back-end fuel cycle, which deals with used fuel generated from PWR. Here is a figure which shows schematic four different fuel cycle option scenarios.

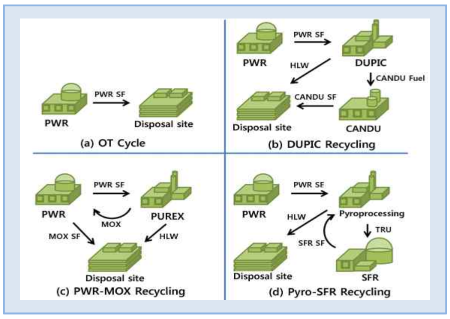


Fig. 1. Four Fuel Cycle Options

Simplified material flow diagram appears in Figure 1.It shows the types of material transported between the nuclear facilities focusing and comparing with the back-end fuel cycle.

Spent fuel generated from PWR still contains part of useful fissile material with differences in the amount depending on initial enrichment and degree of burn-up.

As part of PWR-CANDU joint technology, DUPIC recycle technology was developed so that PWR SF can be used as CANDU fuel if the fission product is removed. DUPIC is simple thermal, mechanical processing process that disposes PWR SF and generates CANDU fuel using OREOX(Oxidation and REduction of OXide fuel) process which is repetitive oxidation-reduction process. Spent DUPIC fuel is transported to the disposal repository without additional recycle process (Figure1(b)).

MOX(Mixed-Oxide) fuel, the mixture of UO2 and PuO2 using recovered U and Pu from PUREX process, can use Pu as fuel in PWR(Figure 1(c)) [2]. We composed PWR-MOX recirculation cycle as a concept of disposal of spent MOX fuel burned at PWR and HLW generated from PUREX process.

With the use of the fast reactor using high speed neutron with high energy, U-235 and TRU can be combusted. TRU can be used as an energy resources, this can be facilitated with TRU that is recovered on PWR back-end of the fuel cycle process. Pyroprocessing, non-aqueous process using hot molten salt medium, allows collection of U from PWR SF and group collection of TRU. TRU would be fabricated into SFR fuel. Spent fuel from the fast reactor can be repetitively recycled with pyroprocessing. As shown in Pyro-SFR recycling scenario (Figure 1(d)), there is no spent fuel finally transported to the disposal repository, and only HLW from pyroprocessing is transported to the disposal repository.

3. Material Flow of Fuel Cycle Option

3.1 Basic database of material flow calculation

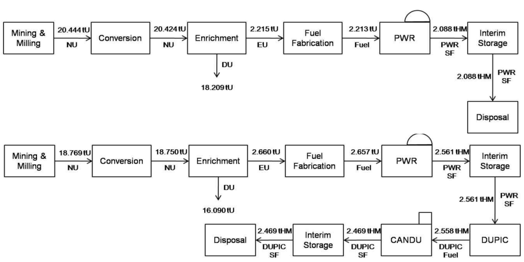
With respect to establish the national policy for fuel cycle option, identification of a fuel cycle option that can be the best suitable for the country and evaluation work on all aspects stated above should be proceeded. For this task, evaluation of material flow concerning fuel cycle option became necessary [3]. This paper analyzes material flow (1 TWh per) and features in steady state on all four of the fuel cycle scenarios by using PyroFlow v1.0.

All the scenarios on system analysis start from the identical front-end fuel cycle and PWR, However, material flow spent on the same amount of power generation appears very differently due to the difference of scenario composition. That is, the required amount of uranium is flexible in accordance with the scenario of back-end of the fuel cycle related to PWR, material flow of front-end fuel cycle containing mining, conversion, enrichment is also flexible in accordance with that.

The fair criteria should be made to be able to study quantitative comparison of the different fuel cycle options because of the fuel cycle scenarios related to the back-end fuel cycle technology along with other types of reactors [4]. This paper set up total 1 TWh amount of power generation and calculates material flow generated between each process.

3.2 Material Flow Analysis

In case of PWR fuel, 4.5 w% initial enrichment and 55 GWd/MtHM discharge burn-up were set up. Fast reactor is a burner reactor having 600MWe and 121 GWd/tHM was used. Material flow of four fuel cycle options is shown in Figure 2.



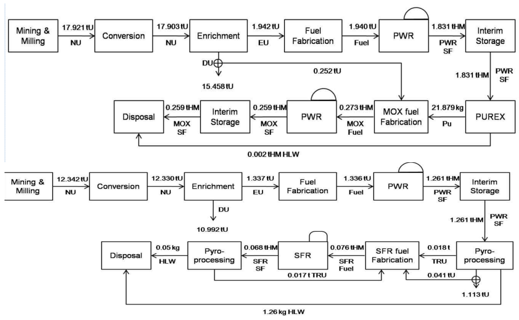


Fig. 2. Material Flow of each fuel cycle scenario

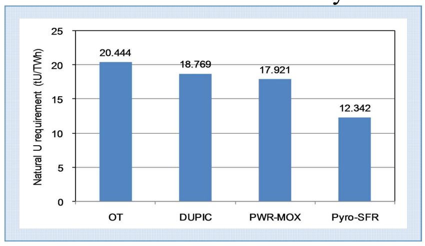


Fig. 3. Natural U requirement by considering Fuel Cycle Option

4. Conclusions

As a result of an analysis on material flow of each nuclear fuel cycle, it was analyzed that Pyro-SFR recycling is most effective on U resource availability among four fuel cycle option.

As shown in Figure 3, OT cycle required the most amount of U and Pyro-SFR recycle consumed the least amount of U. DUPIC recycling, PWR-MOX recycling, and Pyro-SFR recycling fuel cycle appeared to consumed 8.2%, 12.4%, 39.6% decreased amount of uranium respectively compared to OT cycle. Considering spent fuel can be recycled as potential energy resources, U and TRU taken up to be 96% is efficiently used. That is, application period of limited uranium natural resources can be extended, and it brings a great influence on stable use of nuclear energy.

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