Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2015

National Option of China's Nuclear Energy Systems for Spent Fuel Management

R.X. Gao [a,b], W. I. Ko [b*], S. H. Lee [b]
[a] *University of Science and Technology, 217 Gajungro, Yuseong, Daejeon, 305-350, Rep. of Korea*
[b] *Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseung, Daejon 305-353, Rep. of Korea*
[*] *Corresponding author : nwiko@kaeri.re.kr*

1. Introduction

China, like all countries with nuclear energy, shares the challenges to ensure the accumulated nuclear waste would not produce harmful and dangerous effects to the future generation and biosphere. Along with safety concerns, these long standing environmental challenges are the major factors influencing the public acceptance of nuclear power. Although nuclear power plays an important role in reducing carbon emissions from energy generation, this could not fully prove it as a sustainable energy source unless we find a consensus approach to treat the nuclear wastes.

There are currently no countries that have completed a whole nuclear fuel cycle, and the relative comparison of the reprocessing spent fuel options versus direct disposal option is always a controversial issue. Without exception, nowadays, China is implementing many R&D projects on spent fuel management to find a long-term solution for nuclear fuel cycle system transition, such as deep geological repositories for High Level Waste (HLW), Pu Reduction by Solvent Extraction (PUREX) technology, and fast reactor recycling Mixed U-Pu Oxide (MOX) fuels, etc.

This paper integrates the current nation's projects of back-end fuel cycle, analyzes the consequences of potential successes, failures and delays in the project development to future nuclear fuel cycle transition up to 2100. Four transition scenarios were defined: direct disposal, single-recycling in PWR-MOX, recycling in fast reactor after PWR-MOX, direct recycling in fast reactor. We compared the dynamic results of four scenarios and then assessed relative impact on spent fuel management.

2. Methods and Parameters

We built a dynamic model to analyze the mass flow information of the overall nuclear fuel cycle systems in four scenarios. The model consists of five main modules that are interconnected. These modules include the present conditions input, nuclear electricity demand, reactor matrix, front-end and back-end fuel cycle. Information flow and mass flow are reversed among these modules. One module estimates the required facilities and materials in advance. Then it sends information to other modules while receives the required items from the others. As a word, mass flow model is the data source which provides input information for further multi-disciplinary assessments on security, economics, environmental impacts, and others. Fig. 1 shows the flowchart of model composition.

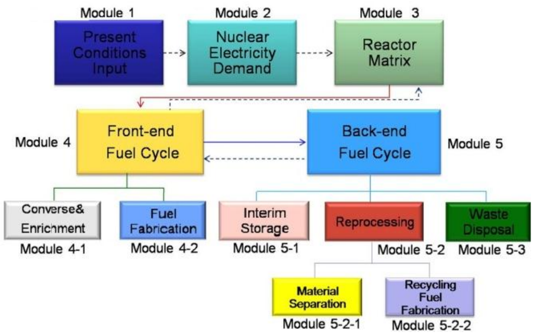

Fig. 1. Flowchart of dynamic model composition.

Table I lists the typical design specifications and characteristics of reference nuclear reactors considered in this study.

Table I: Reactor design specifications and parameters

Reactor type	PWR		PHWR	FR (CR[a] = 1.0)	Unit
	Gen-II	Gen-III			
Model type	M310	CPR-1000	CANDU 6	BN-800	-
Power	1000	1250	728	870	MWe
Thermal efficiency	33	33	33	41.43	%
Capacity factor	85	85	85	85	%
Fuel type	UO_2	UO_2, MOX	UO_2	MOX	-
Discharge burnup	45	55	7.5	100	GWd /tHM
Batch number	3	3	-	3-3.5	-
Lifetime	40	60	40	60	Years
Related scenarios	1,2,3,4	1,2,3,4	1,2,3,4	3,4	-

[a] CR: Conversion Ratio.

3. Results and Discussion

3.1 Accumulation of HLW

We investigated and identified five HLW sources in four scenarios, as listed in Table II. PHWR spent fuel is treated as the HLW to be permanently disposed without any reprocessing process. In Scenarios 2-4, most of accumulated PWR spent fuel could be reused but generates a few HLW during reprocessing and re-fabrication. In Scenarios 2 and 3, PWR-MOX spent fuel is treated as waste and potential fissile material, respectively.

Tables II: HLW sources in four scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
PHWR spent fuels	HLW	HLW	HLW	HLW
PWR-UO_2 spent fuels	HLW	Recycled	Recycled	Recycled
PWR-MOX spent fuels	Not produced	HLW	Recycled	Not produced
PWR spent fuel losses (during reprocessing and re-fabrication)	Not produced	HLW	HLW	HLW
FR spent fuel losses (during reprocessing and re-fabrication)	Not produced	Not produced	HLW	HLW

Fig. 2 shows the accumulated PWR spent fuel. In Scenario 1, along with the rapid expansion of nuclear power, the total amount of PWR spent fuel accumulation will be more than 830 ktHM by 2100. However, in Scenarios 2-4, the PWR spent fuel accumulation could be reduced by 64-80% eventually.

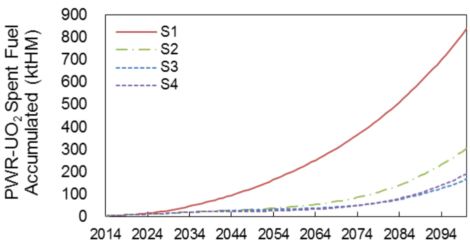

Fig. 2. Accumulation of PWR-UO_2 spent fuel through 2100.

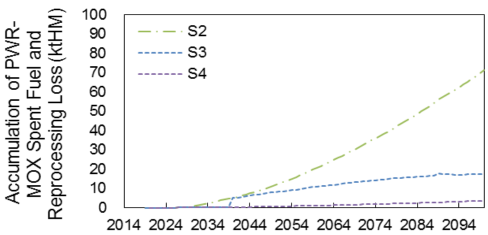

Fig. 3. Accumulation of PWR-MOX spent fuel and reprocessing loss through 2100.

Fig. 3 shows the HLW accumulation of PWR-MOX spent fuel and reprocessing loss. Compared with Scenarios 1 and 3, Scenario 2 generates the largest amount of HLW, as much as 71 ktHM.

3.2 Accumulation of Depleted Uranium

Although it seems that no hazard to treat and dispose the depleted uranium, the related costs are expensive considering the increasing amount of depleted uranium. As shown in Fig. 4, in Scenario 4, the accumulation of depleted uranium could be reduced by 32.8% compared to direct disposal.

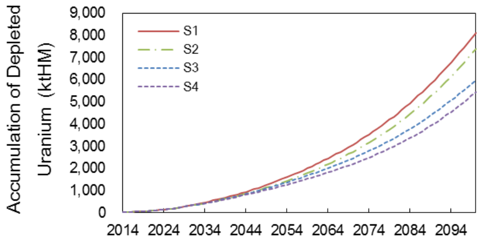

Fig. 4. Accumulation of depleted uranium through 2100.

3.3 Accumulation of Plutonium Inventory

In 2030, commercial PWR-MOX or fast reactors begin to consume Pu reprocessed from PWR spent fuels. As shown in Fig. 5, the stockpile of Pu is significantly reduced by 23.3-63.5% in Scenario 2-4 compared to remaining Pu in un-reprocessed spent fuel of Scenario 1.

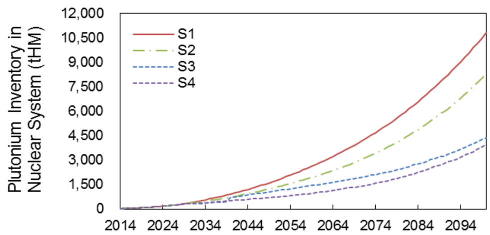

Fig. 5. Accumulation of plutonium inventory in nuclear system through 2100.

4. Conclusions

The result revealed that the fuel cycle transition of reprocessing and recycling of spent fuel would bring advantages to overall nuclear systems by reducing high level waste inventory, saving natural uranium resources, and reducing plutonium management risk.

REFERENCES

[1] The State Council of the People's Republic of China. The 12th five years energy development plan. January 2013. [Online] Available: <http://www.gov.cn/zwgk/2013-01/23/content_2318554.htm> (in Chinese).