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Environmental Sensitivity Studies for Gen-IV Roadmap Fast Reactor Scenario

2004. 3

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제 출 문

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본 보고서를 2004 년도 “건식 재가공 핵연료 노심특성 평가 기술개발” 과제의 기술 보고서로 제출합니다.

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ABSTRACT

The environmental effect of the self-sufficient fast reactor scenario, which is considered as one of the full fissile plutonium and transuranic recycle scenario in Gen-IV roadmap, has been analyzed by using the dynamic analysis method. Through the parametric calculations for the fast reactor deployment time and capacity, the environmental effects of the fuel cycle for important parameters such as the amount of spent fuel and the combined amounts of plutonium and minor actinides were estimated and compared to those of the once-through LWR fuel cycle.

The results of the sensitivity calculations showed that an early deployment of the fast reactor with a high capacity can reduce the accumulation of spent fuel by up to 37%. Furthermore, the recycling of plutonium and minor actinides can reduce the key repository parameter (long term decay heat). Therefore the favorable environmental effects can be expected with the implementation of the symbiotic fast reactor scenario.

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I. Introduction

The full fissile plutonium and transuranic (TRU) recycle fuel cycle scenario introduces both multiple recycle and fast neutron spectrum reactors, which can extend the source of fuel and shrink the source of waste. In the Gen-IV Roadmap[1], three kinds of symbiotic scenario are considered; In the first scenario, LWR UOX once-through plants are deployed paired with a fast burner reactor operating on a closed cycle to manage the back end of the fuel cycle-the goal is to reduce the waste burden destined for the repository from the nuclear energy park overall-while retaining a dominance of LWR UOX once-through plants in the energy mix. The second scenario illustrates the use of fissile self-sufficient fast reactor closed fuel cycles in symbiosis with thermal once-through power plants to both manage the waste from the entire energy park and to reduce dependence on virgin ore reserves. The third scenario illustrates the efficacy of converting already deployed fast reactors from a burning (or fissile-self sufficient) operation to breeding at the appropriate time as the way to cap virgin ore withdrawals when economic conditions favor the switchover-with no degradation of the continuing waste management function

In this study, environmental effects of the fissile self-sufficient (BR=1.0) fast reactor scenario have been analyzed by using the dynamic analysis code DYMOND [1,2]. The important parameters affect to the environment such as the amount of spent fuel, plutonium and fission products, were analyzed and compared. For the sensitivity studies, two cases were considered; FR deployment time and FR capacity. For the FR deployment sensitivities, the deployment time varies from 2015 to 2030, and for FR capacity sensitivities, the deploying FR capacities varied by 0%, -5%, -10% and -15% of total deployed capacity.

In Chapter II, the results are described for FR deployment time, and the results of the deployment capacity are discussed in Chapter III. Finally, Summary and conclusion are given in Chapter IV.

II. Sensitivities of FR Deployment Time

The basic fuel cycle scenario is same as that of the Gen-IV Road map case. It assumes that all of the spent LWR and FR fuel are reprocessed and recycled in FR with the recovered MA. In this study, the FR deployment time with the LWR and MOX spent fuel reprocessing time has been changed, which in shown in Table II.1.

II.1 Deployment time of 2015

A summary for the results of this scenario is shown in Figures II.1.1 The LWR SF reaches a peak around the year 2015. Beyond the year 2015 it starts to decrease and eventually goes to zero at the year 2065.

The amount of the unused PU varies with the FR capacity, and it is 0.28 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2450 and 185 kt, respectively.

II.2 Deployment time of 2020

A summary for the results of this scenario is shown in Figures II.2.1 The LWR SF reaches a peak around the year 2020. Beyond the year 2020 it starts to decrease and eventually goes to zero at the year 2065.

The amount of the unused PU varies with the FR capacity, and it is 2.4 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2530 and 183 kt, respectively

II.3 Deployment time of 2025

A summary for the results of this scenario is shown in Figures II.3.1 The LWR SF reaches a peak around the year 2025. Beyond the year 2025 it starts to decrease and eventually goes to zero at the year 2082.

The amount of the unused PU varies with the FR capacity, and it is 4.4 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2620 and 188 kt, respectively.

II.4 Deployment time of 2030

A summary for the results of this scenario is shown in Figures II.4.1 The LWR SF reaches a peak around the year 2030, Beyond the year 2030, it starts to decrease and reaches 17 kt at the year 2100.

The amount of the unused PU varies with the FR capacity, and it is 6.2 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2700 and 188 kt, respectively.

II.5 Comparison for each deployment time

A comparison results among the deployment time are summarized in Figure II.5.1 Figure II.5.1 shows the variation of the burned uranium, unused plutonium and FP. The burned uranium varies from 2450 kt to 2700 kt between year 2015 and 2030 of deployment time.

Also, it can be seen that the amount of unused plutonium increases from 0.28 kt to 6.22 kt between deployment time 2015 and 2030. However, the variation of the amount of the FP is very small.

III. Sensitivities of FR Capacity

In this Chapter, the sensitivities have been investigated for the FR capacity variation. The variation of the FR capacity is shown in Table III.1.

III.1 0% Reduction of Capacity%

A summary for the results of this scenario is shown in Figures III.1.1 The LWR SF reaches a peak around the year 2015. Beyond the year 2015 it starts to decrease and eventually goes to zero at the year 2065.

The amount of the unused PU varies with the FR capacity, and it is 0.28 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2450 and 185 kt, respectively.

III.2 5% Reduction of Capacity

A summary for the results of this scenario is shown in Figures III.2.1 The LWR SF reaches a peak around the year 2015, Beyond the year 2015, it starts to decrease and eventually goes to zero at the year 2065.

The amount of the unused PU varies with the FR capacity, and it is 7.3 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2650 and 186.3 kt, respectively.

III.3 10% Reduction of Capacity

A summary for the results of this scenario is shown in Figures II.4.1 The LWR SF reaches a peak around the year 2015. Beyond the year 2015 it starts to decrease and eventually goes to zero at the year 2060.

The amount of the unused PU varies with the FR capacity, and it is 14.2 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 2850 and 188.9 kt, respectively.

III.4 15% Reduction of Capacity

A summary for the results of this scenario is shown in Figures II.4.1 The LWR SF reaches a peak around the year 2015. Beyond the year 2015 it starts to decrease and eventually goes to zero at the year 2060.

The amount of the unused PU varies with the FR capacity, and it is 21.2 kt at the year 2100. The burned uranium and FP increase with time. The amounts of burned uranium and FP at the year 2100 are 3040 and 190.3 kt, respectively.

III.5 Comparison of each deployment capacity

A comparison results among the deployment time are summarized in Figure III.5.1, which shows the variation of the burned uranium, unused plutonium and FP. The burned uranium varies from 2450 kt to 3040 kt between 0% reduction and 15% reduction of the FR capacity.

Also, it can be seen that the amount of unused plutonium increases from 0.28 kt to 21.2 kt between the FR capacity reduction 0% and 15%. However, the FP increases slightly.

IV. Summary and Conclusion

The environmental effects of the FR (BR=1.0) fuel cycle have been investigated through the sensitivities of deployment time and capacity. For the environmental analysis, the important parameters such as the amount of SF, uranium, Pu and FP have been calculated and compared each other.

From the sensitivities of the deployment time, it can be summarized as follows:

- If the deployment time is delayed from the year 2015 to 2030, the amount of total SF and burned uranium increase 17 kt and 250 kt, respectively.
- If the deployment time is delayed from the year 2015 to 2030, the amount of unused Pu increases ~6 kt. And, the increasing of FP is ~2%.

From the sensitivities of the deployment capacity, it can be summarized as follows:

- If the deployment capacity is reduced by 15%, the amount of burned uranium increases 590 kt.
- If the deployment capacity is reduced by 15%, the amount of unused Pu increases ~21 kt. And, the increasing of FP is ~3%.

From the above results, it can be seen that the deployment time and capacity can affect to the environment, therefore it can be concluded that earlier deployment with higher deployment capacity of the FR can reduce the environmental impacts.

REFERENCES

1. US-Department of Energy, “A Technology Roadmap for Generation IV Nuclear Energy Systems,” GIF-002-00, Dec. 2002.
2. J. H. PARK and A. M. YACOUT, “Modeling Report of DYMOND Code (DUPIC Version)”, KAERI/TR-2472/2003, KAERI (2003)

Table II.1 FR Deployment Time

Case	FR Deployment Time	LWR SF Reprocessing Time	FR SF Reprocessing Time
1	2015	2010	2015
2	2020	2015	2020
3	2025	2020	2025
4	2030	2025	2030

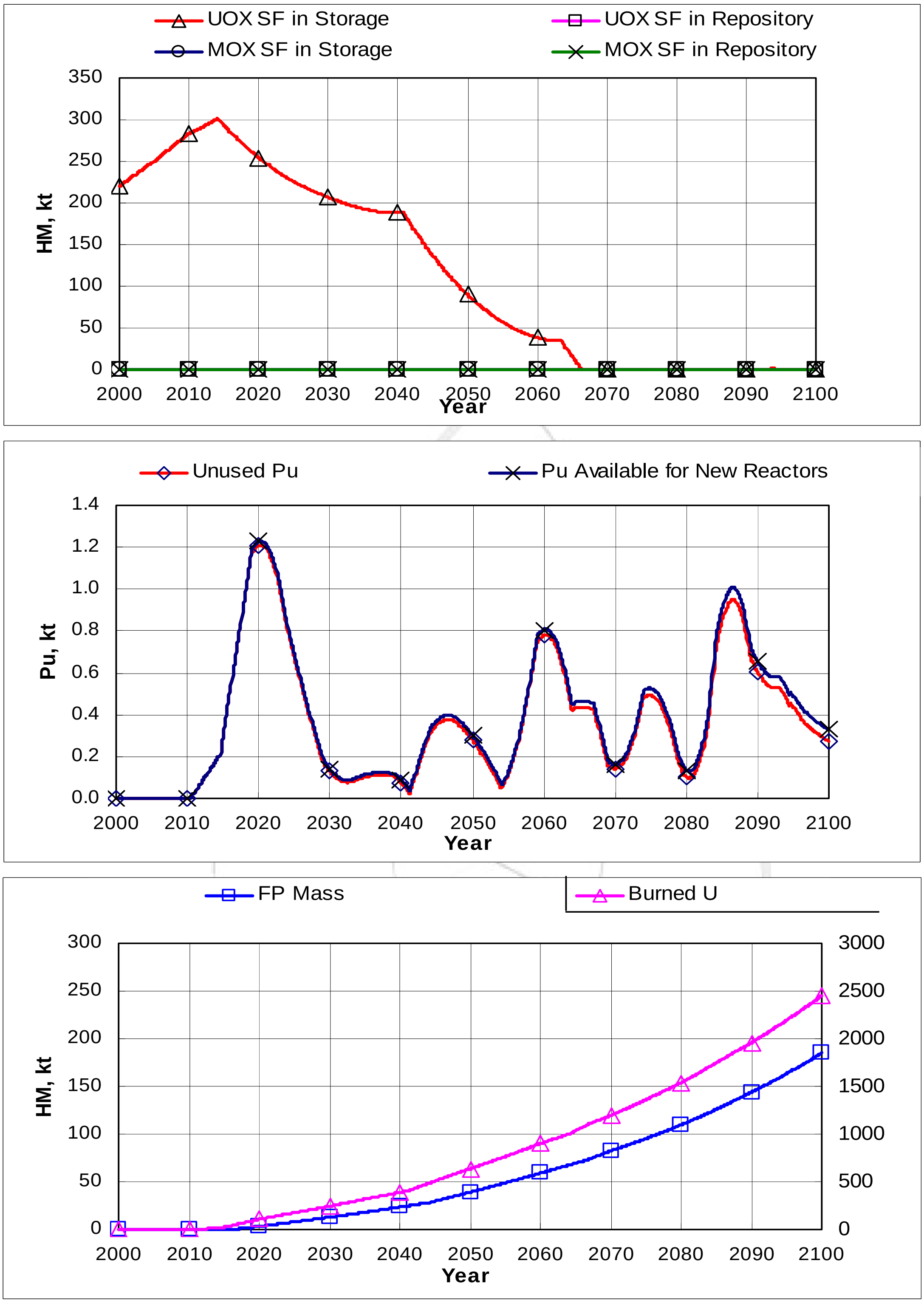

Fig. II.1.1 Amount of Heavy Elements (2015)

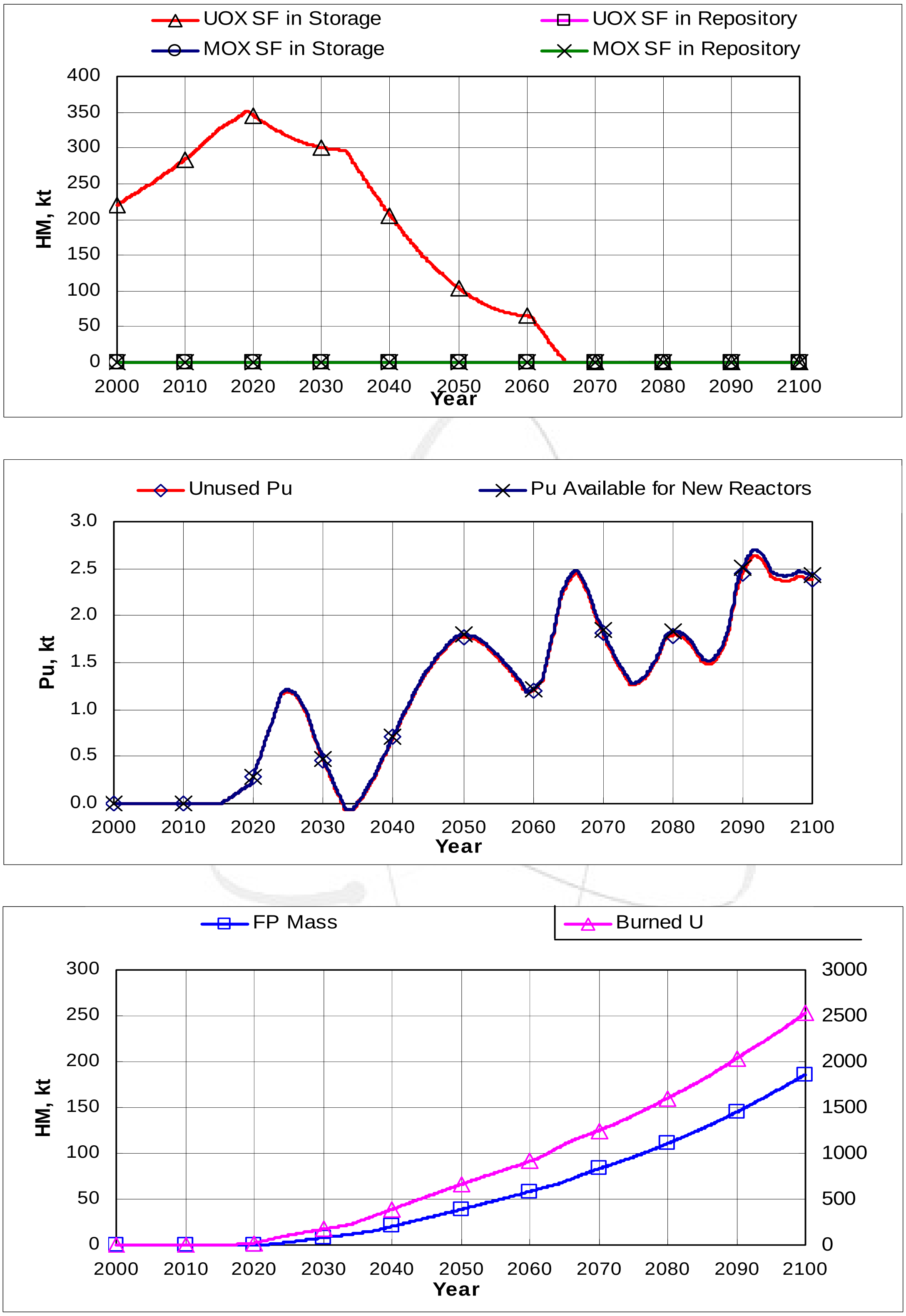

Fig. II.2.1 Amount of Heavy Elements (2020)

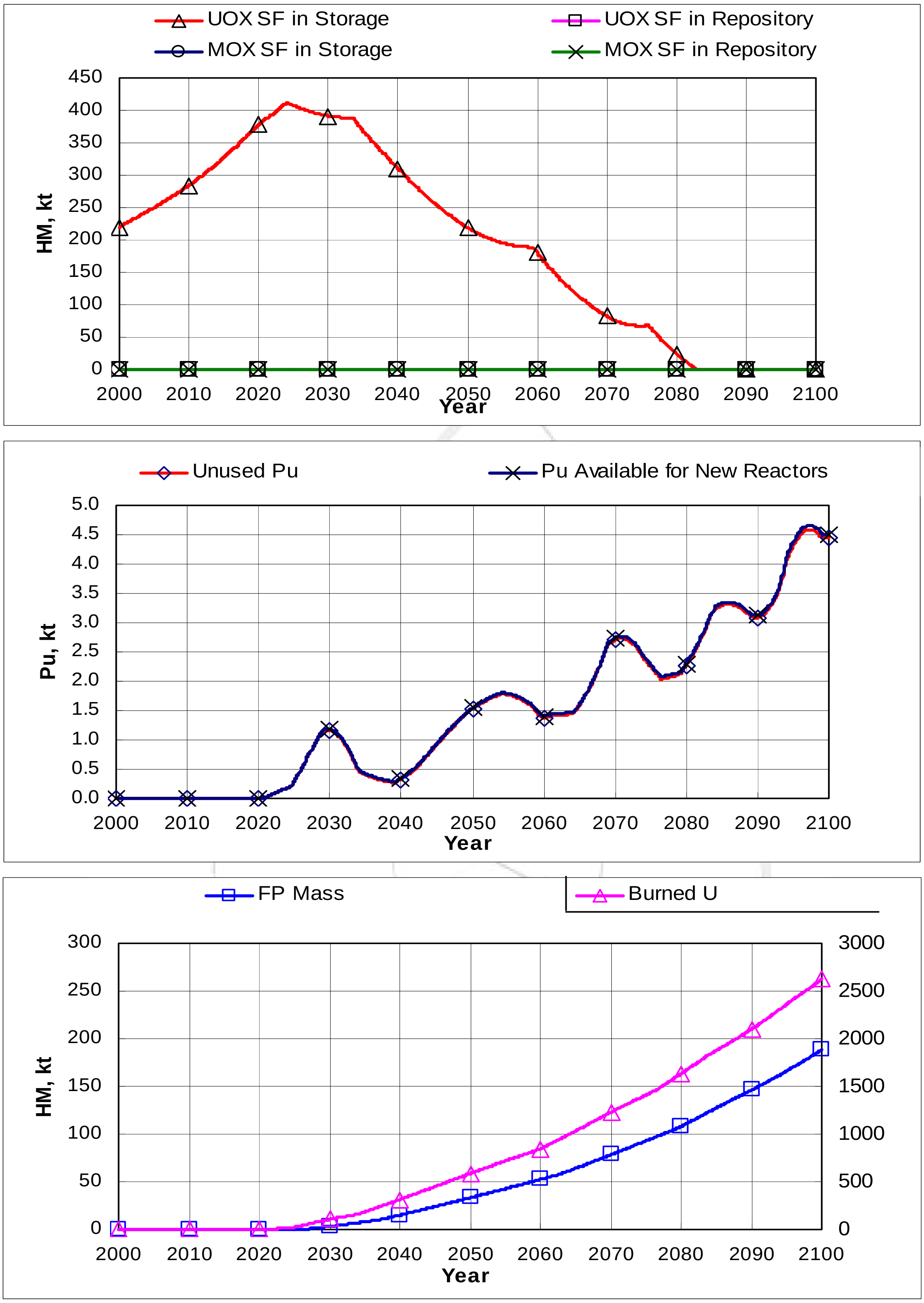

Fig. II.3.1 Amount of Heavy Elements (2025)

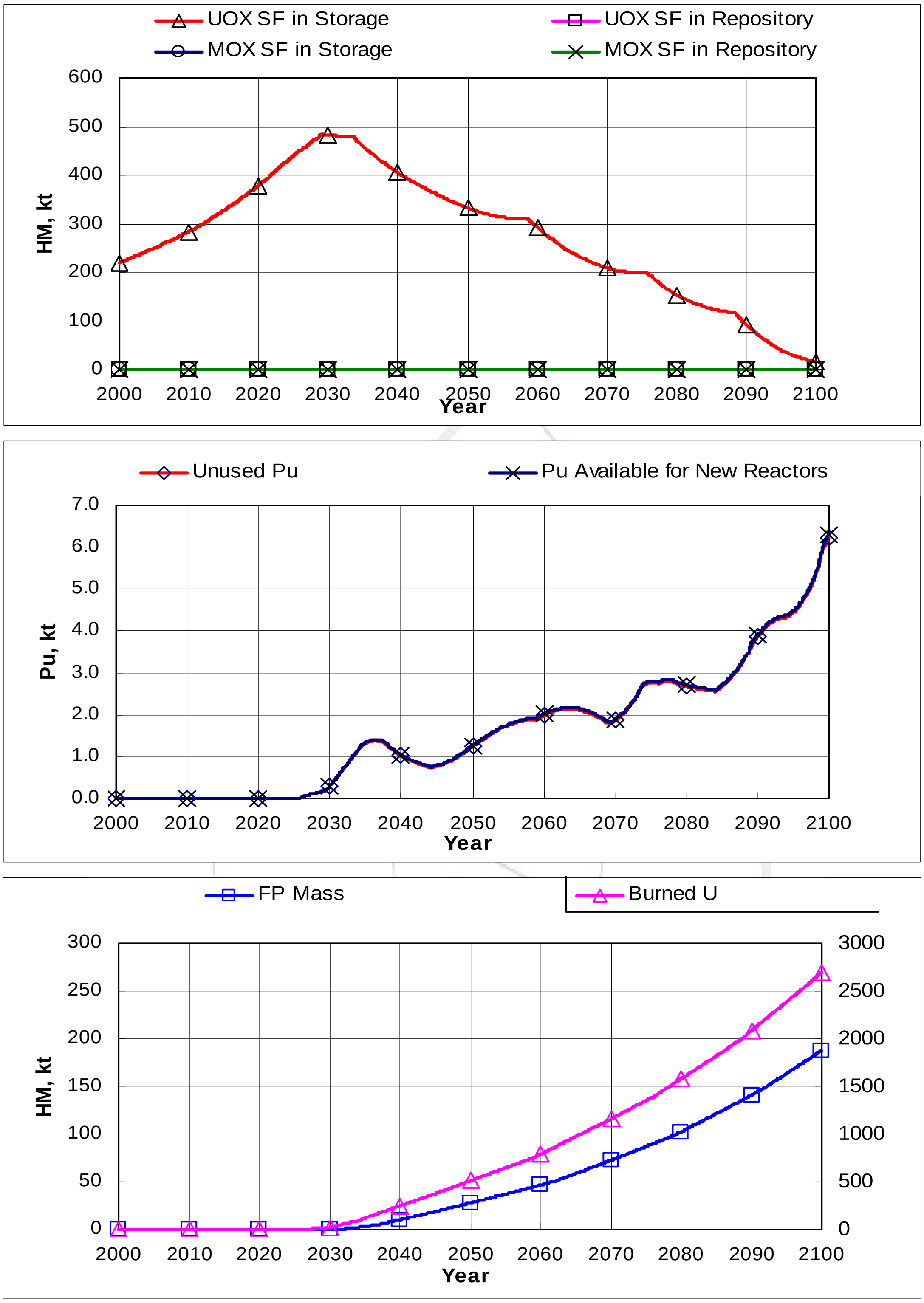

Fig. II.4.1 Amount of Heavy Elements (2030)

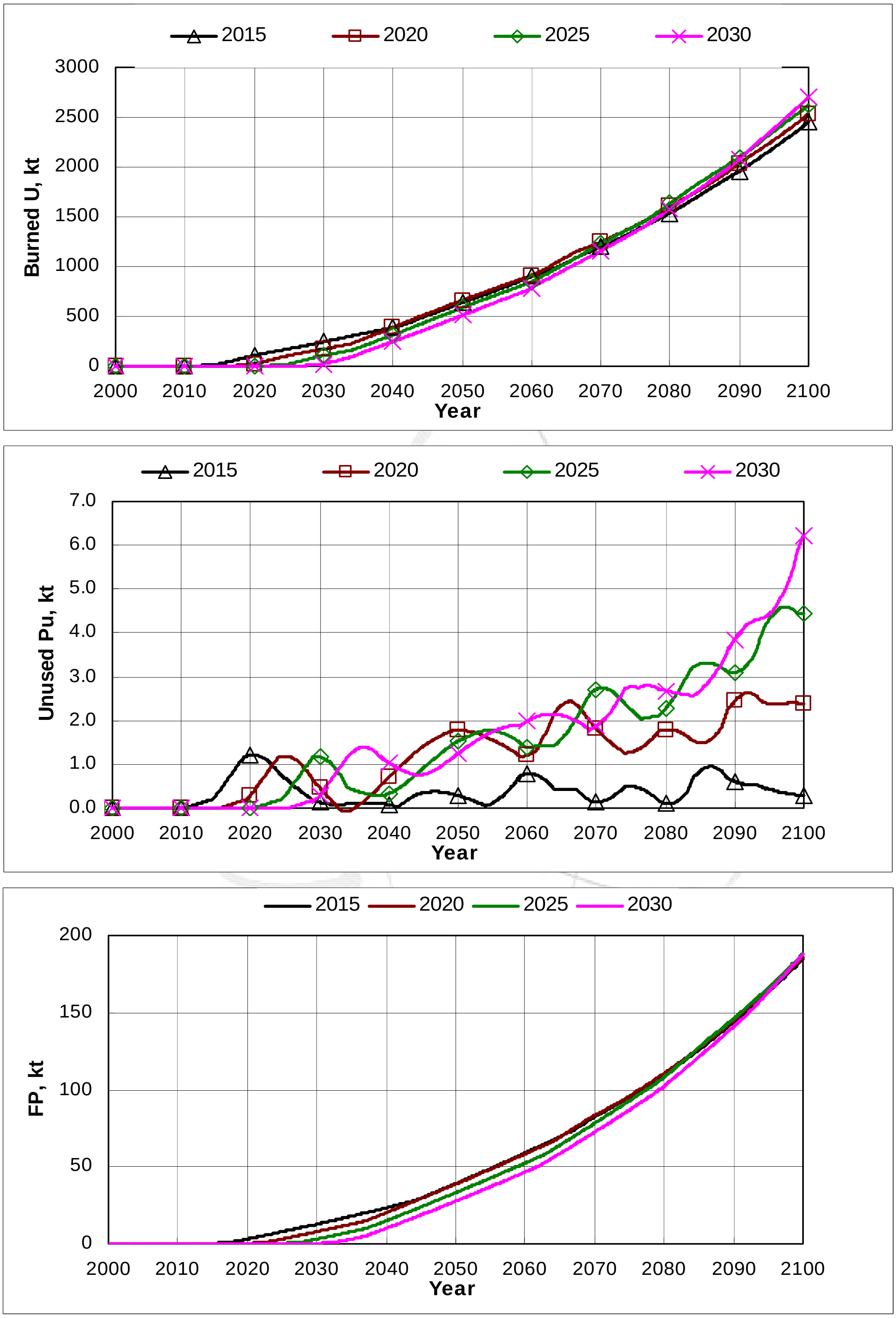

Fig. II.5.1 Comparison of Amount of Heavy Elements

Table III.1 FR Capacity (%) with Time

Year	Case 1	Case 2	Case 3	Case 4
2000	0	0	0	0
2005	0	0	0	0
2010	0	0	0	0
2015	60	55	50	45
2020	45	40	35	30
2025	25	20	15	10
2030	25	20	15	10
2035	30	25	20	15
2040	40	35	30	25
2045	40	35	30	25
2050	15	10	5	0
2055	40	35	30	25
2060	35	30	25	20
2065	20	15	10	5
2070	35	30	25	20
2075	30	25	20	15
2080	50	45	40	35
2085	40	35	30	25
2090	40	35	30	25
2095	40	35	30	25
2100	40	35	30	25

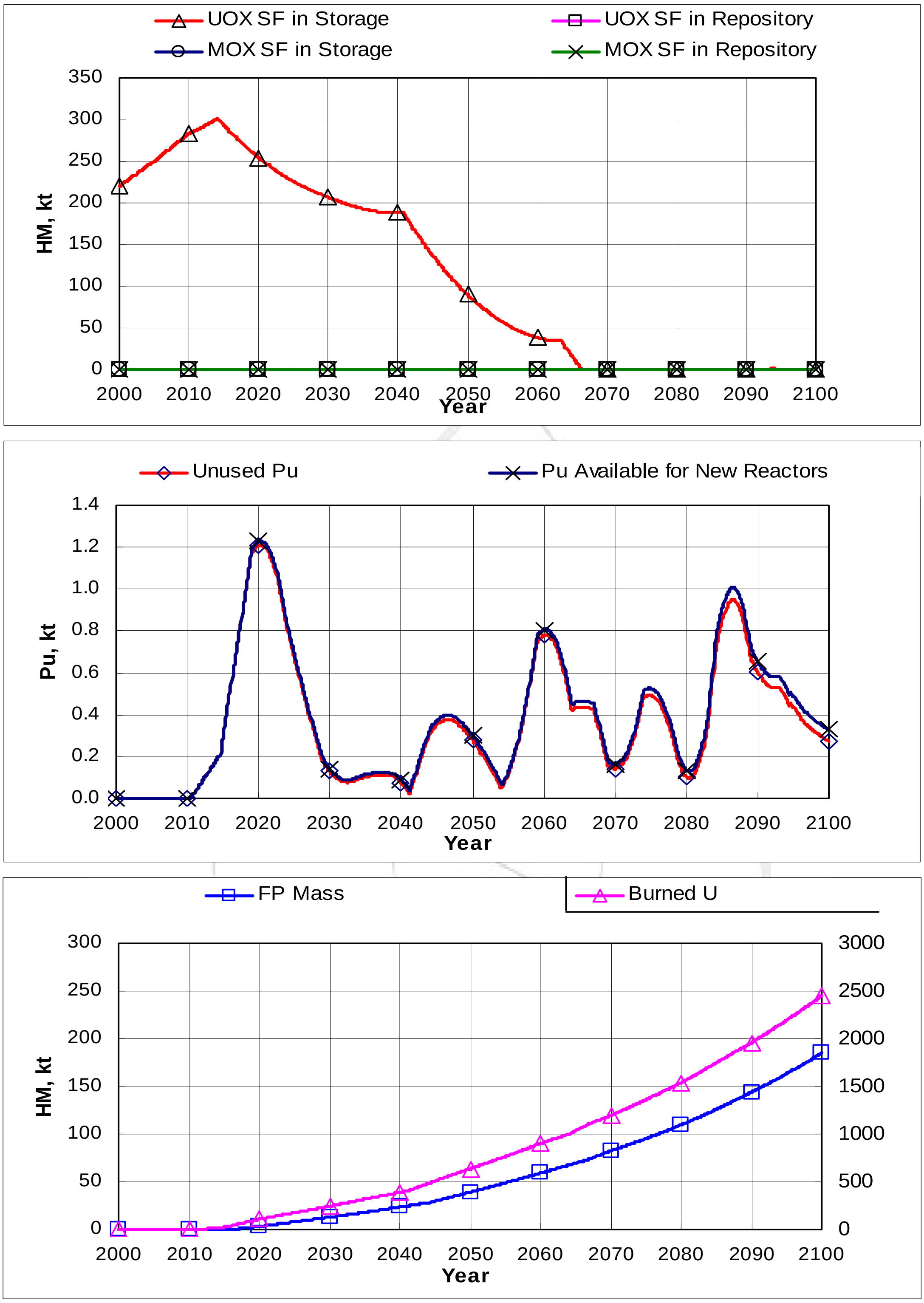

Fig. III.1.1 Amount of Heavy Elements (0% Capacity Reduction)

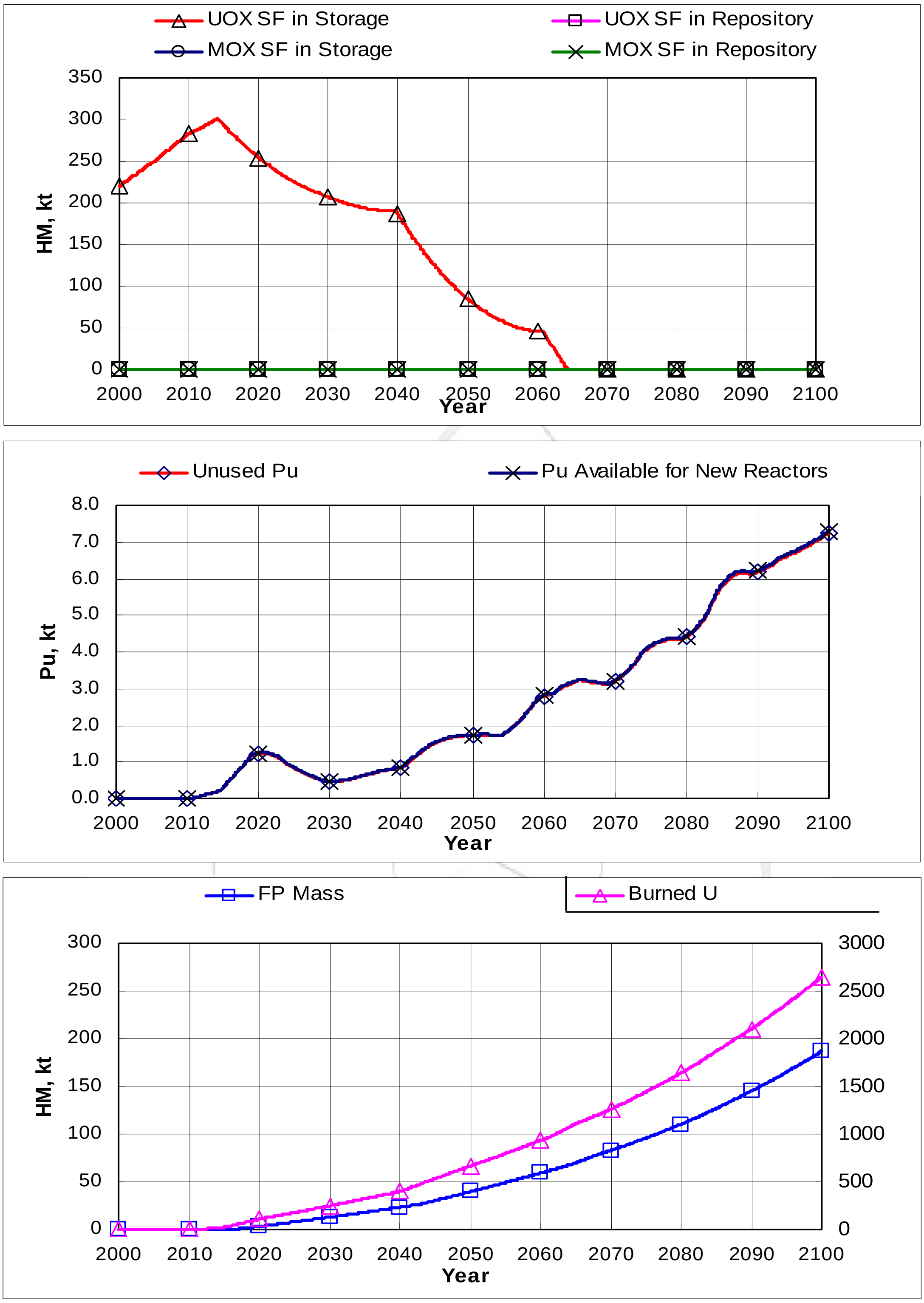

Fig. III.2.1 Amount of Heavy Elements (5% Capacity Reduction)

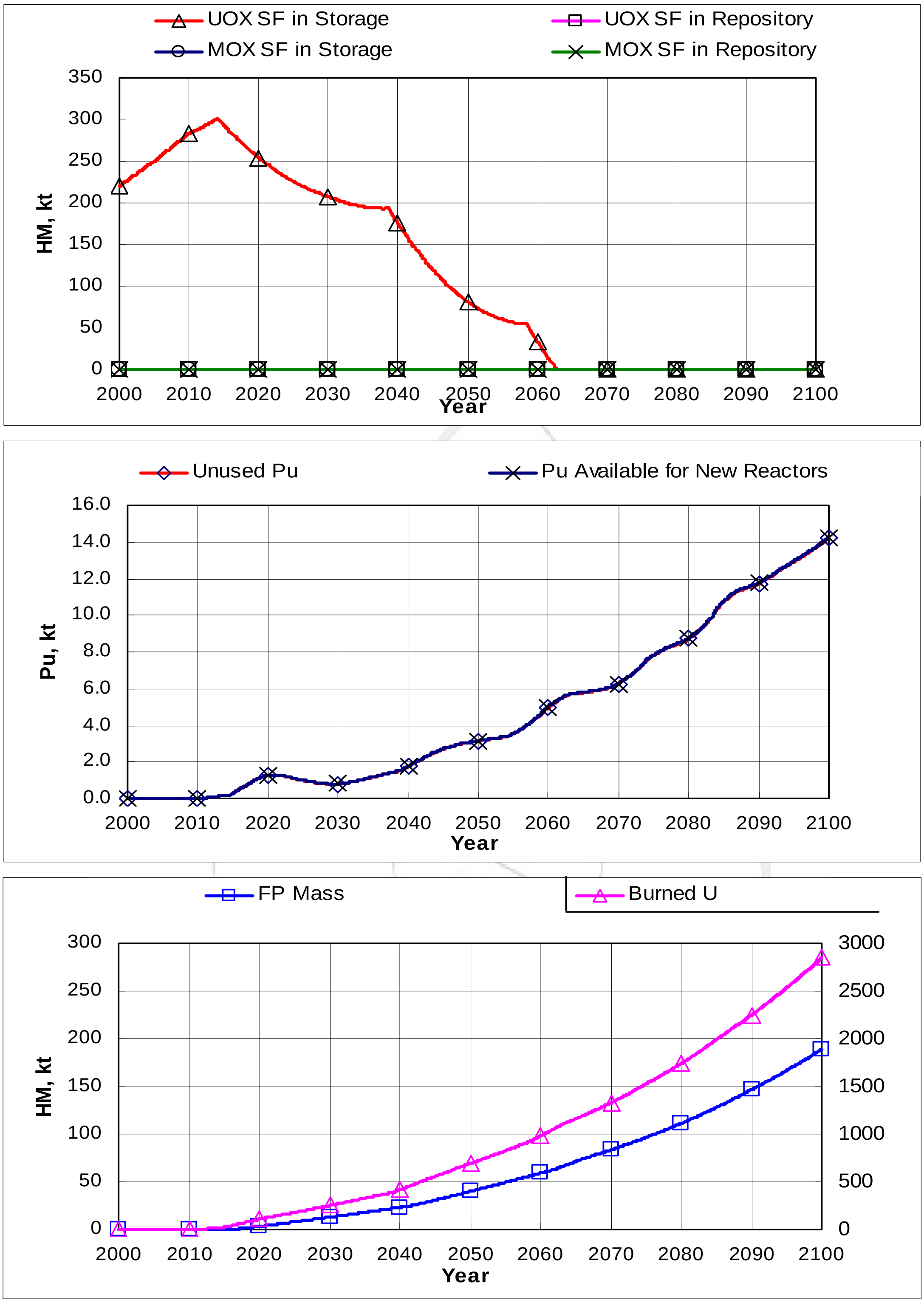

Fig. III.3.1 Amount of Heavy Elements (10% Capacity Reduction)

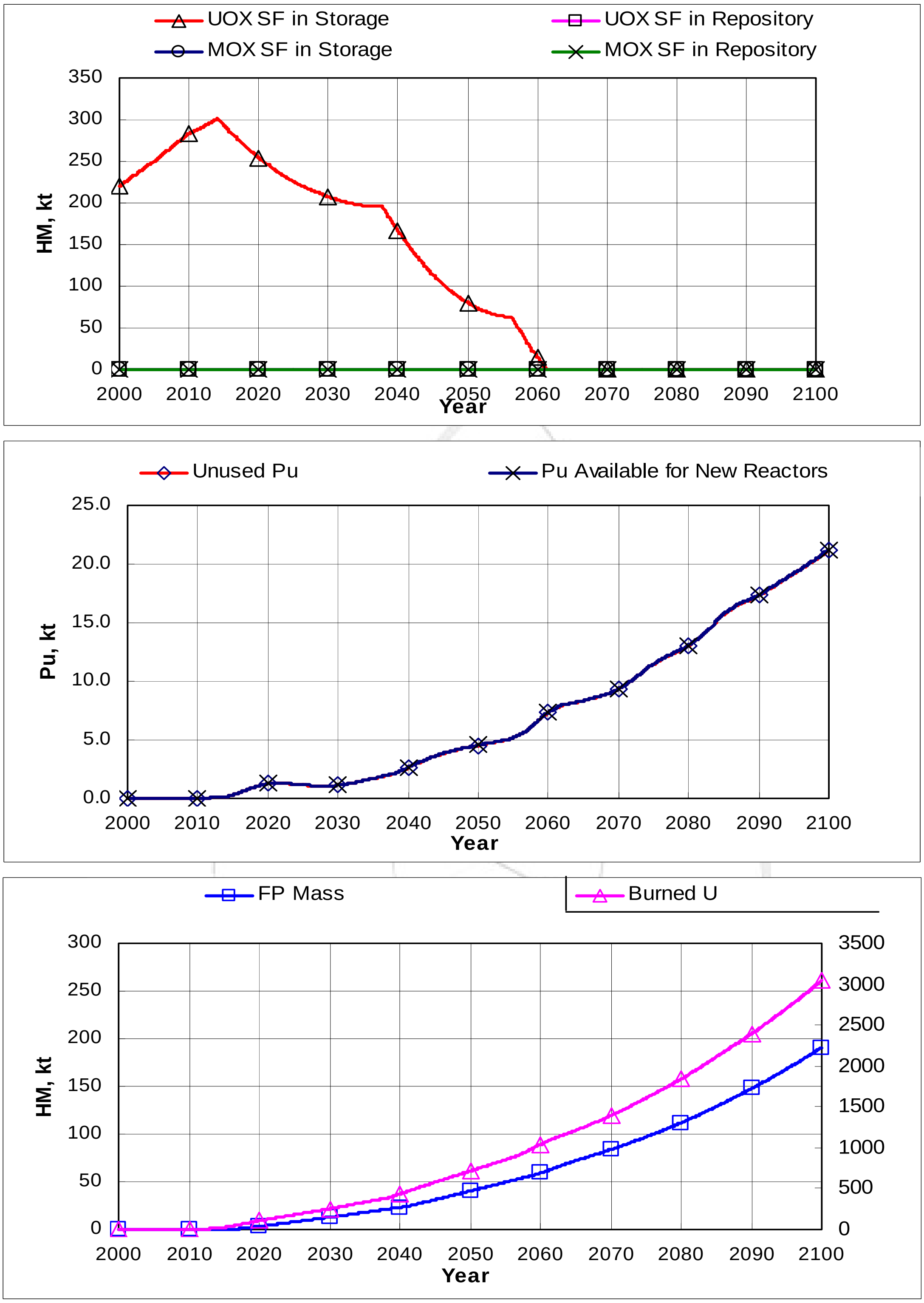

Fig. III.4.1 Amount of Heavy Elements (15% Capacity Reduction)

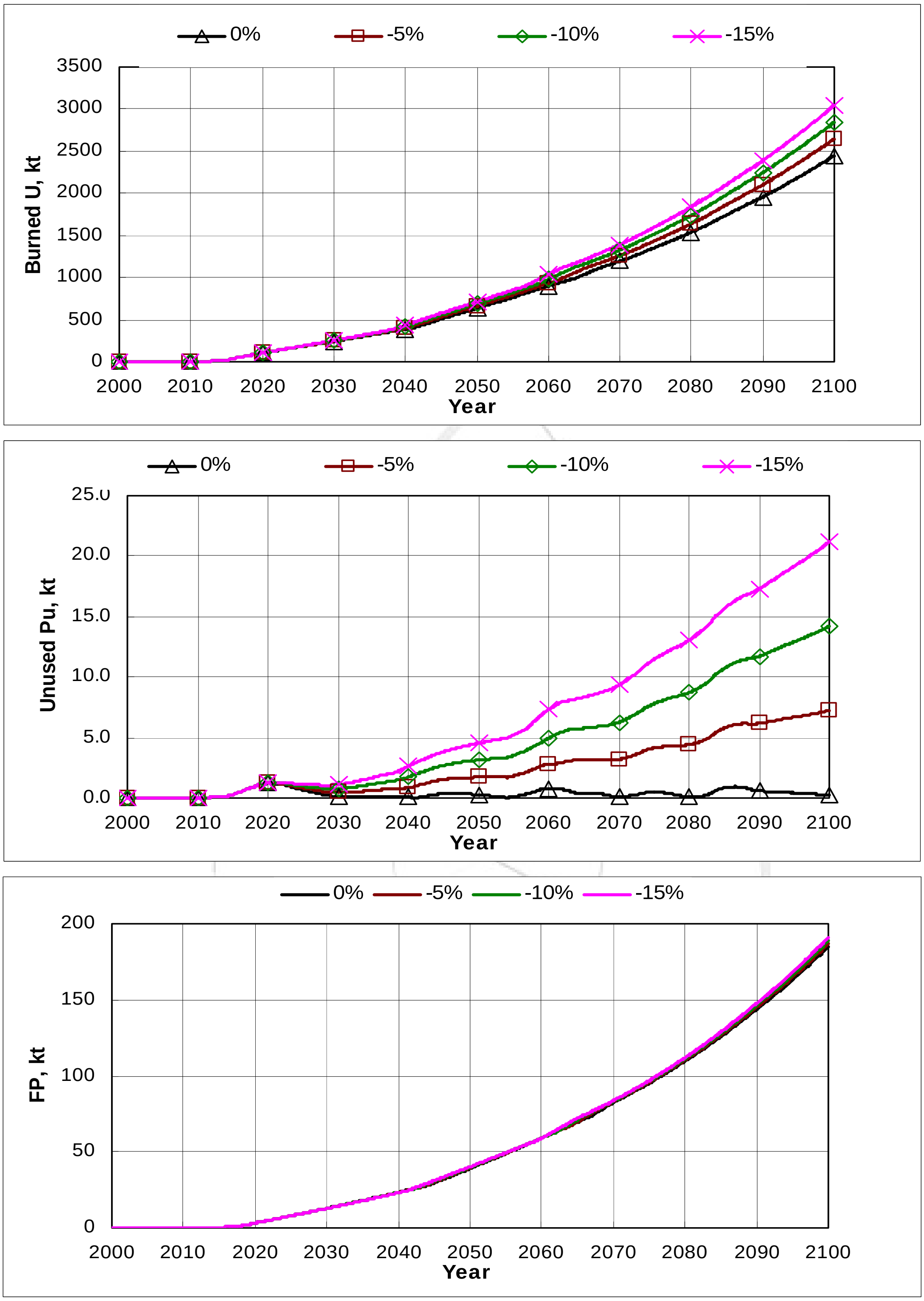

Fig. III.5.1 Comparison of Amount of Heavy Element

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서지정보양식

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초록 (15-20줄내외)

제 4 세대 원전 roadmap 에서 플루토늄 및 초우란 원소의 전체 재순환 시나리오의 하나로 검토되고 자기-유지형 (증식비=1.0) 고속로 시나리오에 대한 환경 영향을 동적 분석 방법론을 사용하여 분석하였다. 고속로의 도입 시기와 도입 용량에 대한 민감도 분석을 통하여 핵연료 주기의 중요한 인자인 사용후 핵연료 양과 이에 따른 플루토늄 발생량을 평가하고, 이 결과들을 경수로 비순환 주기와 비교하였다.

민감도 분석 결과, 고속로의 용량을 높게 하고 도입 시기를 빠르게 하면 사용후 핵연료 발생량을 약 37% 감소시킬 수 있는 것으로 나타났다. 또한, 플루토늄 및 minor actinide 가 재순환 됨에 따라 주요 처분장 인자중의 하나인 장기 붕괴열을 감소시킬 수 있는 것으로 나타났다. 따라서, 공생적인 고속로 시나리오의 도입으로 긍정적인 환경 영향을 기대할 수 있다.

주제명키워드 (10단어내외)	자기-유지형 고속로, 플루토늄, 초우란 원소, 재순환, 제4세대 원전 roadmap, 동적 분석 방법, 환경 영향, 사용후 핵연료

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Abstract (15-20 Lines)

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Subject Keywords (About 10 words)	self-sufficient fast reactor, plutonium, transuranic, recycle, Gen-IV roadmap, dynamic analysis, environmental effect, spent fuel