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Dynamic Modeling of the Korean Nuclear Fuel Cycle

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Abstract

The Korean fuel cycle scenario has been modeled by using the dynamic analysis method. For once-through fuel cycle model, the nuclear power plant construction plan was considered, and the nuclear demand growth rate from the year 2016 was assumed to be 1%. After setup the once-through fuel cycle model, the DUPIC and fast reactor scenarios were modeled to investigate the environmental effect of each fuel cycle. Through the calculation of the amount of spent fuel, and the amounts of plutonium and minor actinides were estimated and compared to those of the once-through fuel cycle. The results of the once-through fuel cycle shows that the demand grows to 64 GWe and the total amount of the spent fuel would be 100 kt in the year 2100, while the total spent fuel can be reduced by 50% when the DUPIC scenario is implemented

Keywords: fuel cycle, dynamic analysis, once-through, nuclear demand, DUPIC cycle, spent fuel

I. Introduction

The Korean fuel cycle has been modeled and analyzed using the dynamic analysis code of DYMOND [1, 2]. During the current century, the nuclear power was assumed to grow from 13.716 GWe in 1999 to 27.32 GWe in 2015 [3]. From the year 2016 to 2100, the growth rate was assumed to be 1%.

In the once-through model, the current operating reactors (12 PWR and 4 PHWR) are considered. And, there will be no construction of PHWR after 2000. After setting up the once-through model, the DUPIC scenario was analyzed.

The DUPIC (Direct Use of Spent PWR Fuel in CANDU Reactors) scenario involves a partial recycle of LWR spent fuel (SF) materials in CANDU reactors. The LWR SF is mechanically separated into two major streams: (1) the UO_2 with fission products and actinides and (2) the SF cladding. The UO_2 with fission products and actinides is fabricated into CANDU fuel assemblies. These fuel assemblies are then used to feed CANDU reactors and then disposed of as SF in a geological repository. For the DUPIC scenario, the deployment time was assumed 2015 (with the DUPIC fabrication start time of 2010).

II. Once-Through Fuel Cycle

In this fuel cycle, current operating reactors are considered: 12 PWRs and 4 PHWRs. In the fuel cycle model, the reactor life time was assumed to be 40 yr for both the PWR and PHWR. Also, all the PHWRs were assumed to be shutdown after their life time.

Figure 1 shows the deployment of fuel cycle services and reactors needed to meet energy demand. In 2100, the demand was expected to be 63.7 GWe. Though, the deployed capacity varies with the demand, it is not exactly same as the demand. After 2040, PWR dominates the demand. The number of PWRs in the year 2100 was expected to be 67 with the reactor power of 1 GWe. The number of PWR orders is varied with the deployed capacity.

Figure 2 gives the amount of the SF, U and PU in the SF. The SF increases with time, and the total SF will be 100.8 kt in the year 2100. Beyond 2049, the PHWR SF remains constant at ~17 kt. The total amount of U and Pu in SF will be 94.2 kt and 1.2 kt, respectively. The amount of MA and FP are shown in Fig. 3. It can be seen that the total amount of MA and FP in the SF will be 0.13 kt and 5.2 kt, respectively.

III. DUPIC Scenario

The DUPIC scenario [4, 5] has been analyzed too. It is assumed that the current PHWRs are operated as PHWR itself, while the new DUPIC reactor will be constructed from 2015. The DUPIC reactor capacity with time is shown Table I.

Figure 4 shows the deployment of fuel cycle services and reactors needed to meet energy demand. The demand and deployed capacity are almost the same as those of the once-through case. Beyond 2020, the PWR sharing of the capacity deceases, ultimately it goes down to ~80% in 2100. On the other hand, the remaining DUPIC capacity increases to ~20% in 2100. The number of PWR and DUPIC reactors increase, and they reach 53 and 19, respectively in 2100. The number of PWR and DUPIC reactor orders vary with the deployed capacity.

Figure 5 represents the amount of the SF, U and PU in the SF. The PWR SF decreases with time and becomes ~0 kt, while the DUPIC SF dominates after 2040. The total SF will be 49.2 kt in 2100. Beyond the year 2049, the PHWR SF remains constant at ~17 kt. The total amount of U and Pu in SF will be 46.6 kt and 0.53 kt, respectively. The amount of MA and FP are shown in Fig. 6. It can be seen that the total amount of MA and FP in the SF will be 0.08 kt and 2.1 kt, respectively.

IV. Summary and Conclusion

The Korean nuclear fuel cycles have been investigated. After setting up the once-through model, DUPIC scenario was analyzed.

From the once-through scenario, it can be summarized as follows:

- The demand grows up to 63.6 GWe in the year 2100.
- The total SF and U in SF are 100.8 kt and 94.2 kt , respectively in the year 2100.
- The amount of Pu, MA and FP in SF are 1.2 kt, 0.13 kt and 5.2 kt, respectively in the year 2100.

From the DUPIC scenario, it can be summarized as follows:

- The amount of total SF and U in SF are reduced by ~50% compared with the once-through cycle.
- The amount of total Pu and FP in SF are reduced by ~60% compared with the once-through cycle. And, the amount of MA in SF is reduced by ~40%

From the above results, it is known that the DUPIC or FR scenario can drastically reduce the spent material which can affects environment.

References

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5. W.I. KO, H. CHOI and M. S. YANG, "Economic Analysis on Direct Use of Spent Pressurized Water Reactor Fuel in CANDU Reactors (IV) – DUPIC Fuel Cycle Cost", *Nuclear Technology*, **134**, 167 (2001)

Table I DUPIC Reactor Capacity (%) with Time

Time	DUPIC Capacity
2000	0
2005	0
2010	0
2015	25
2020	25
2025	25
2030	25
2035	22
2040	22
2045	22
2050	22
2055	20
2060	20
2065	20
2070	20
2075	20
2080	20
2085	20
2090	20
2095	20
2100	20

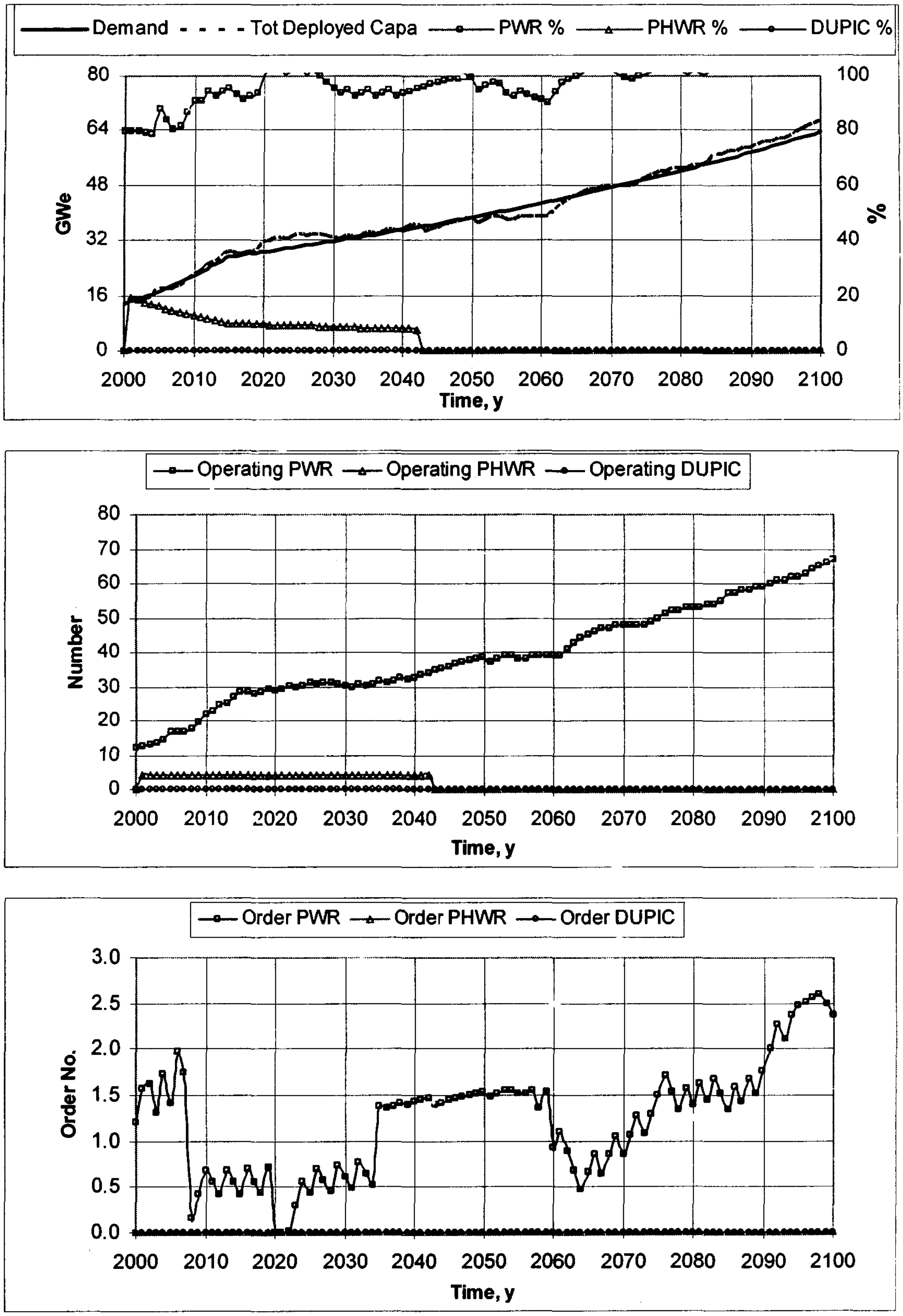


Fig. 1 Reactor with Demand (Once-through)

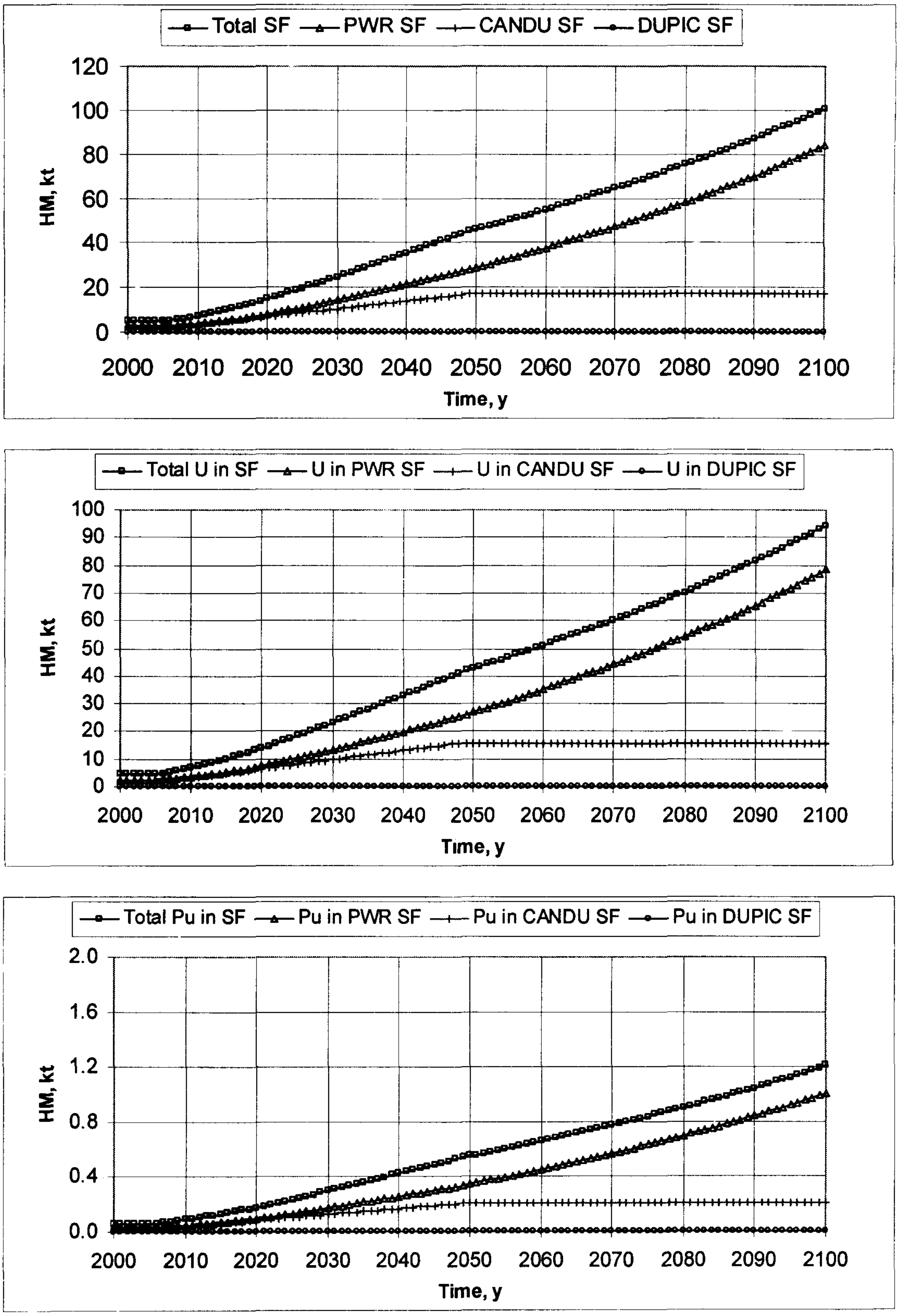
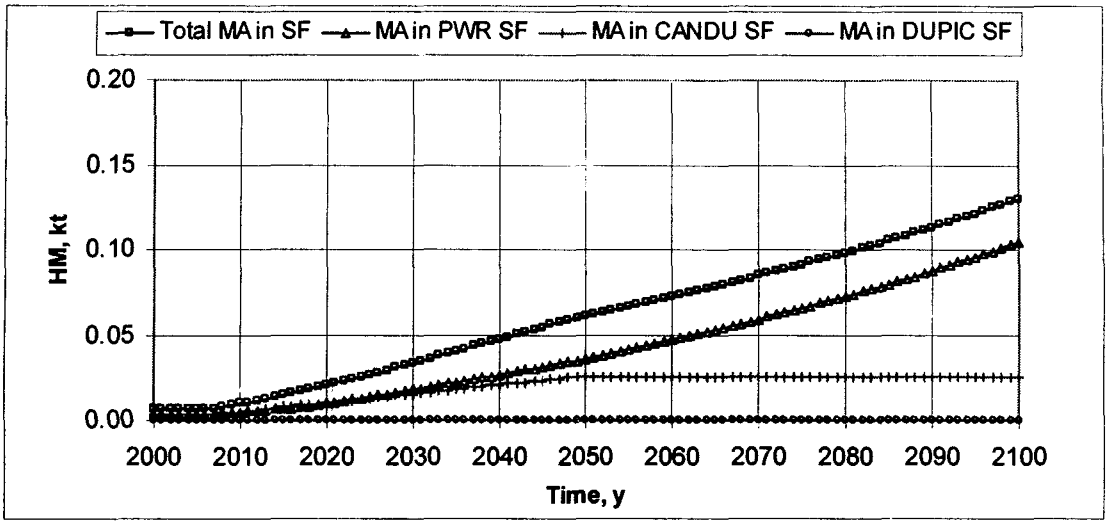


Fig. 2 Spent Fuel and Heavy Element (Once-through)



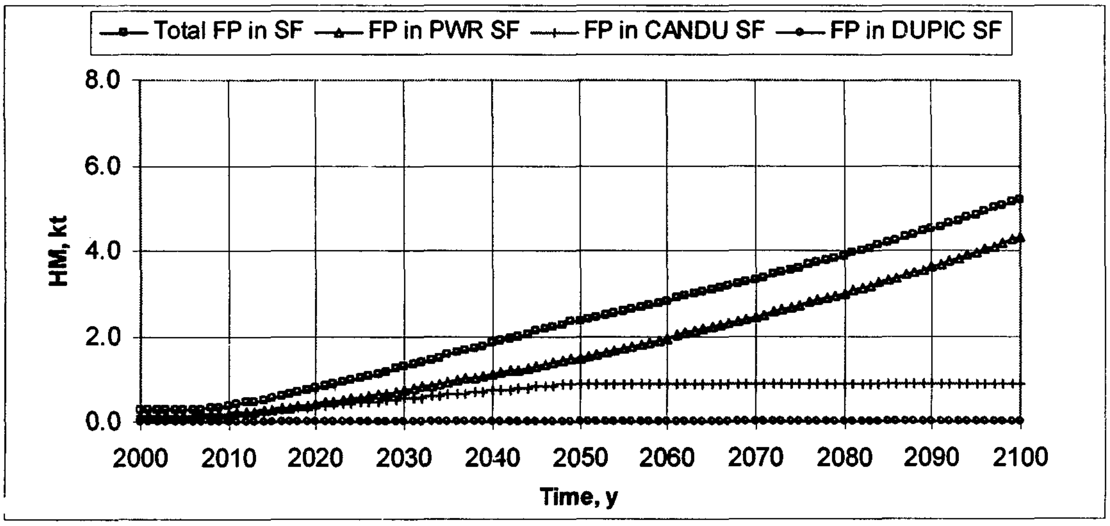


Fig. 3 Heavy Elements (Once-through)

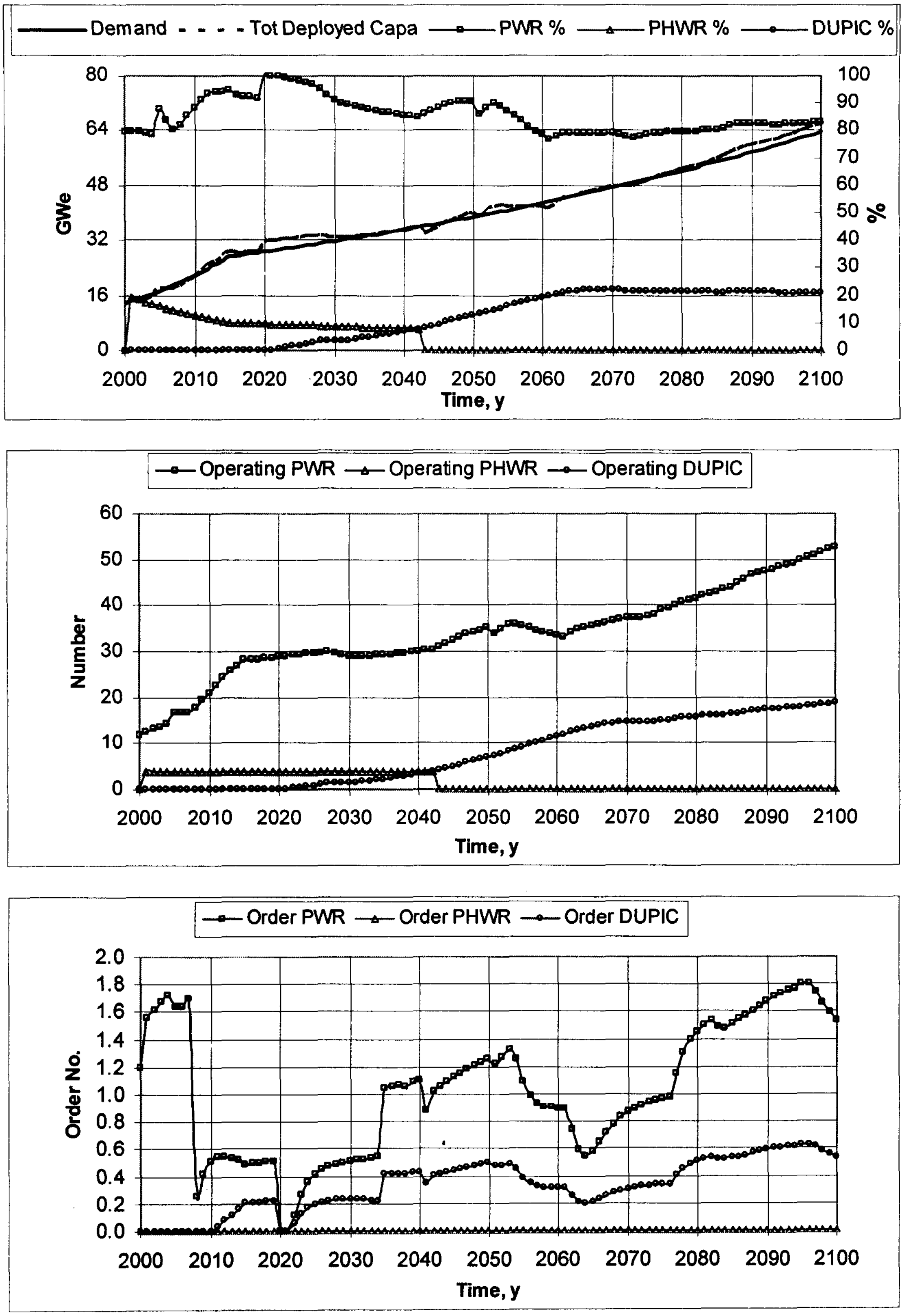


Fig. 4 Reactor with Demand (DUPIC)

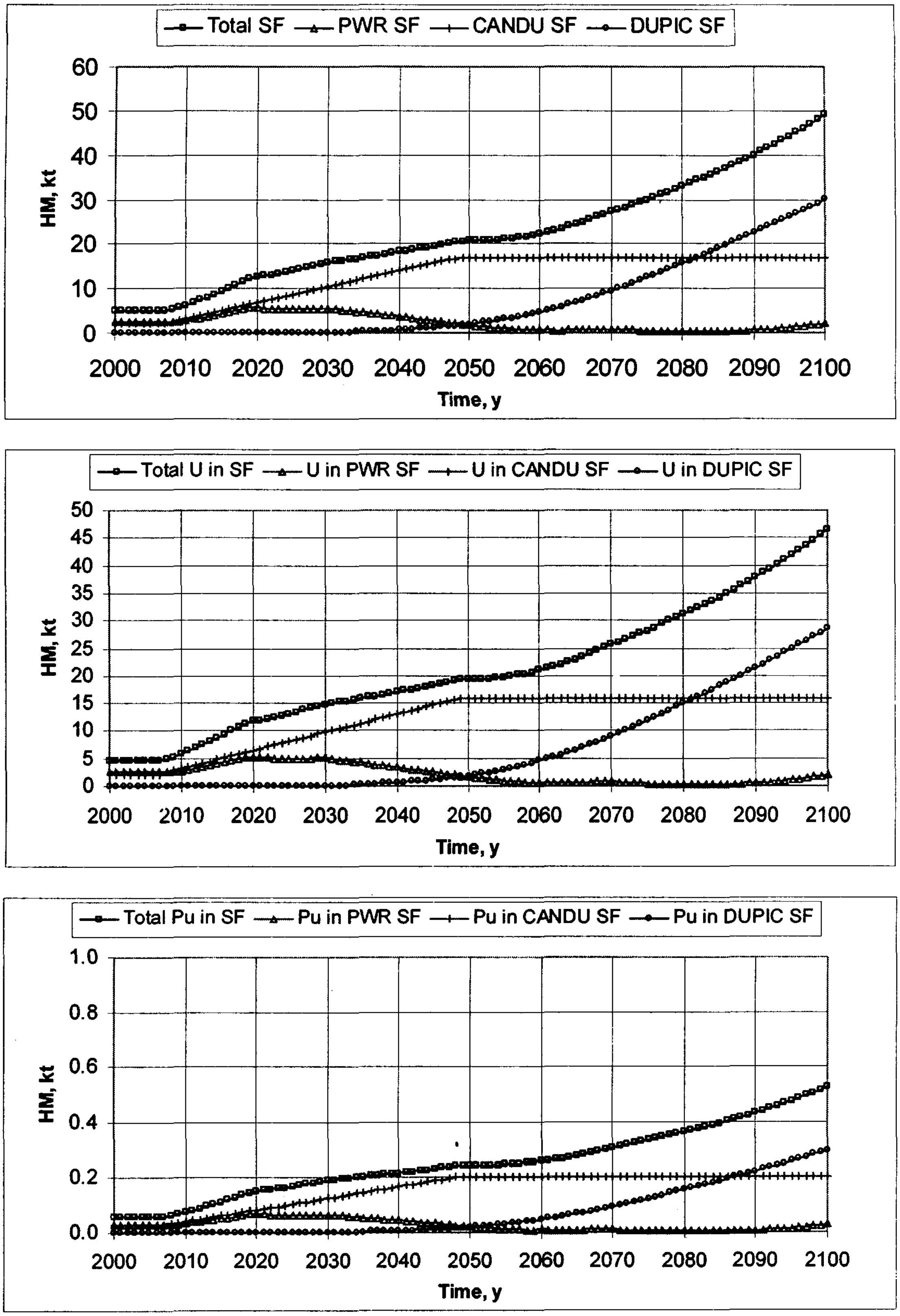
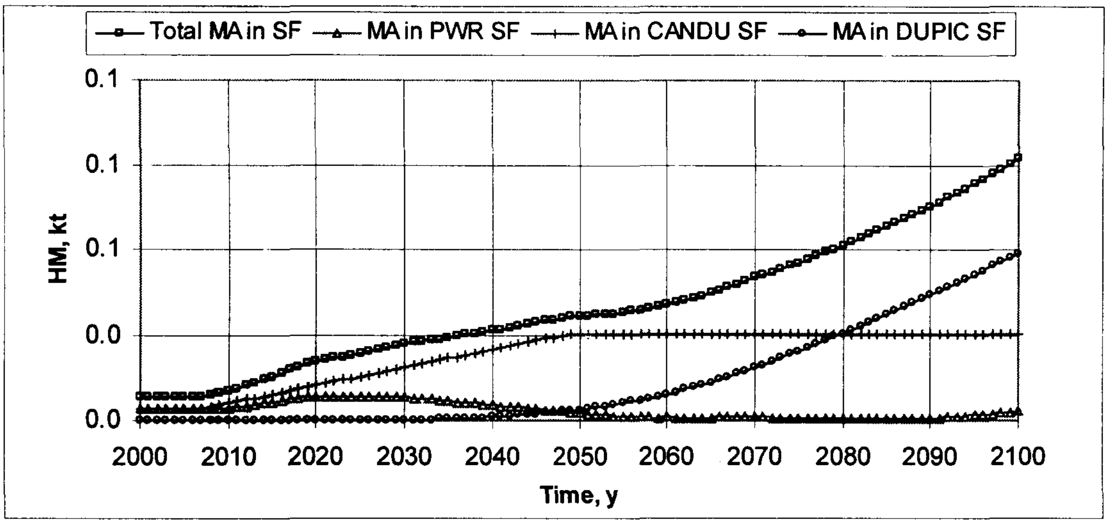


Fig. 5 Spent Fuel and Heavy Elements (DUPIC)



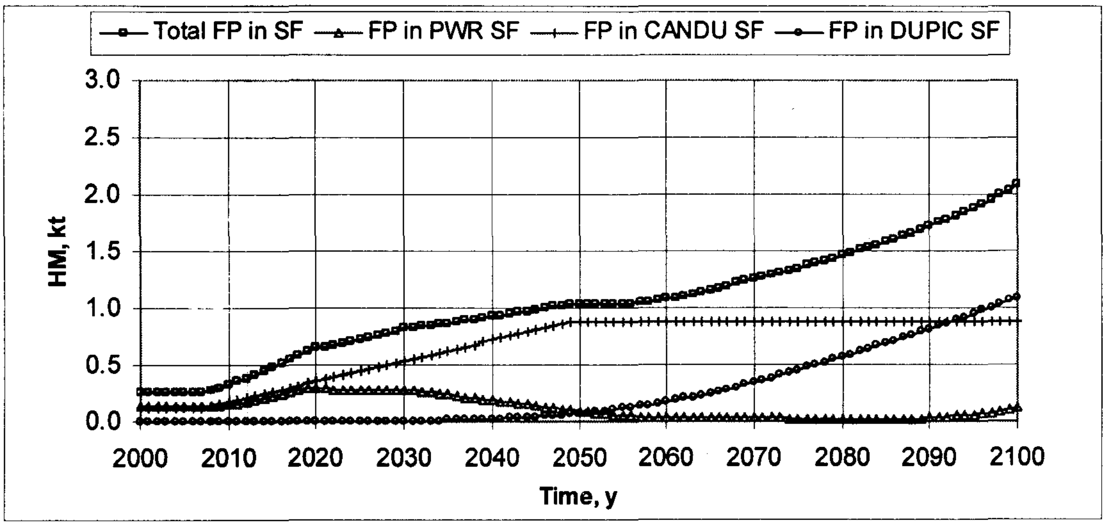


Fig. 6 Heavy Elements (DUPIC)