Safety Analysis of Direct Recycling of Nuclear Spent Fuel in Light Water Reactor (LWR)

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Outline

- *Background*
- *Objective*
- *Methodology*
- *Results and Discussion*
- *Conclusion*

Background

Nuclear Energy Industry grows with 3 main issues:

- *Reactor safety: Multi-barrier System : Defence at Depth*
- *Nuclear Proliferation: political aspects*
- *High level wastes (HLW) management*

➔ *The truly problem in nuclear energy*

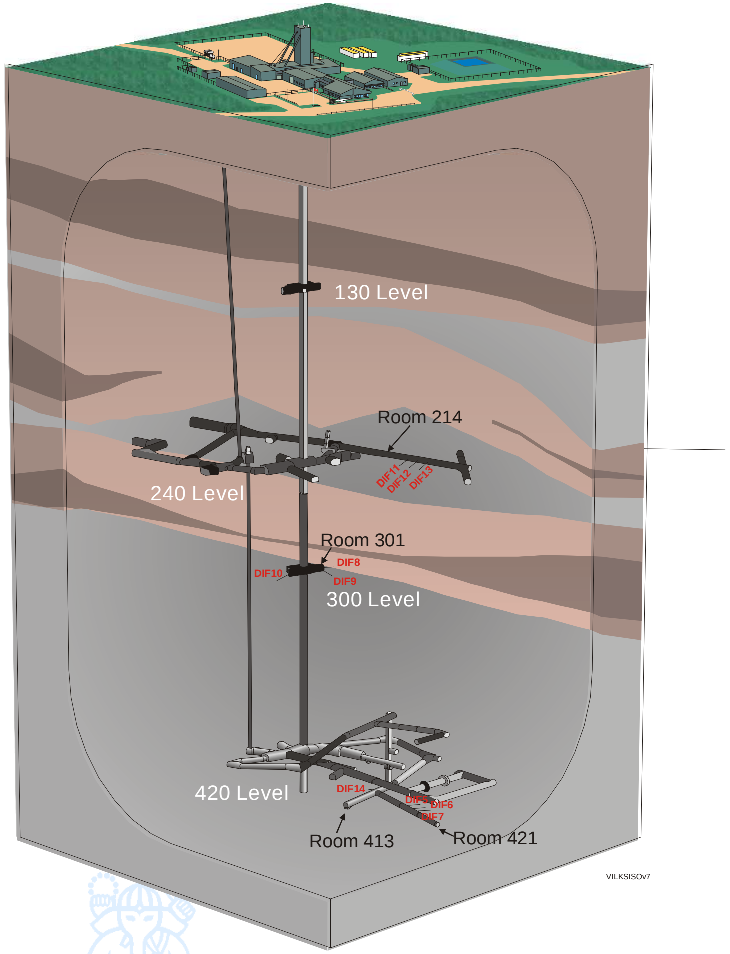
⇩

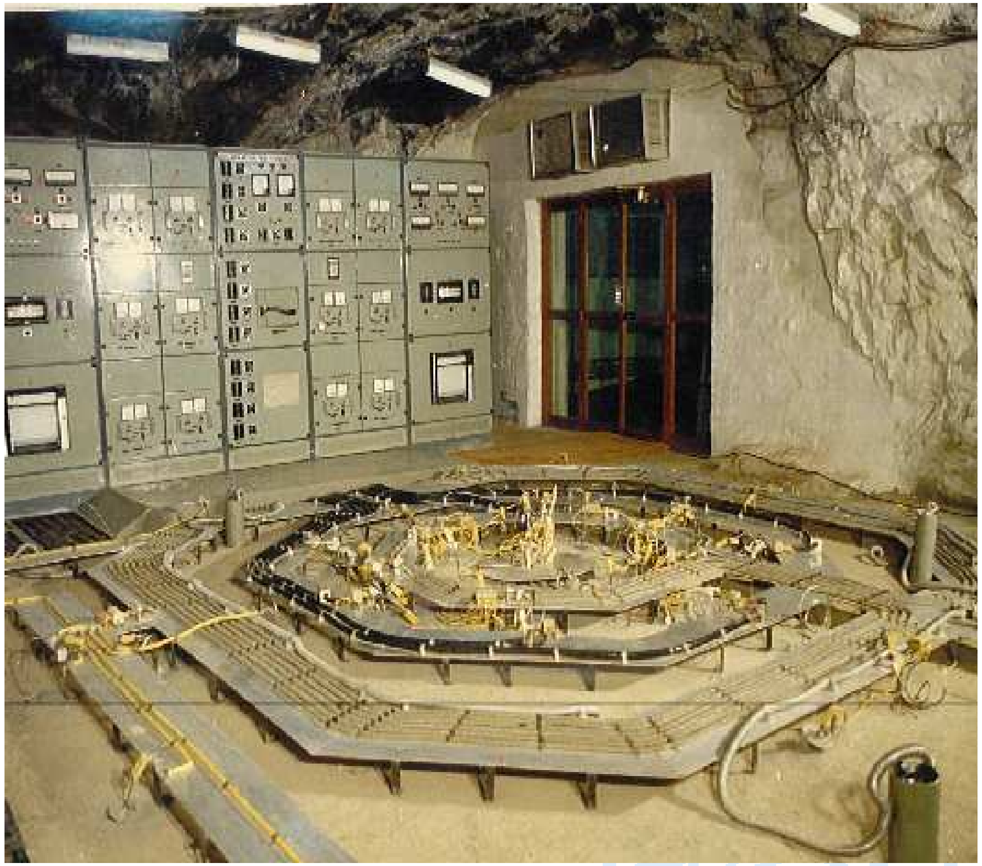
if we can manage HLW, public acceptance will increase

Background …

- Once countries decide to “go nuclear” they may think about “HLW repository site” or at least “underground research laboratory (URL)”

Underground Research Laboratories





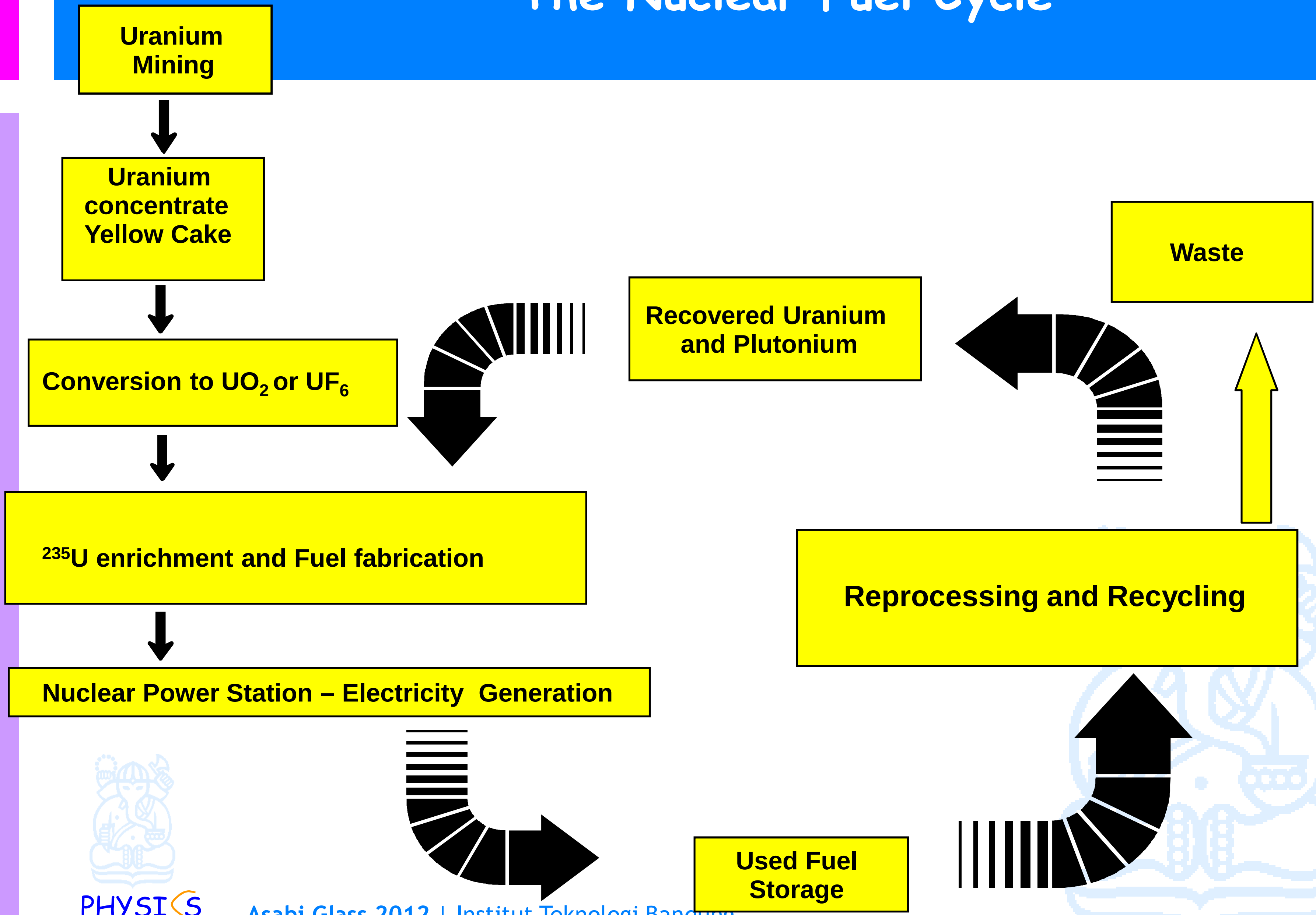
Site specific URL:Lac de Bonnet , Canada

Generic URL: Kolar Gold Field, India

Background …

- They may to choose "*closed cycle strategy*" to recycle HLW in any type reactor or hybrid systems (including *ADS(accelerator driven system)*)
  ➔reprocessing plant is required
- Its very difficult to have country's own reprocessing plant, besides it is very expensive.
- Even OECD countries likes Korea is not allowed to has a reprocessing plant

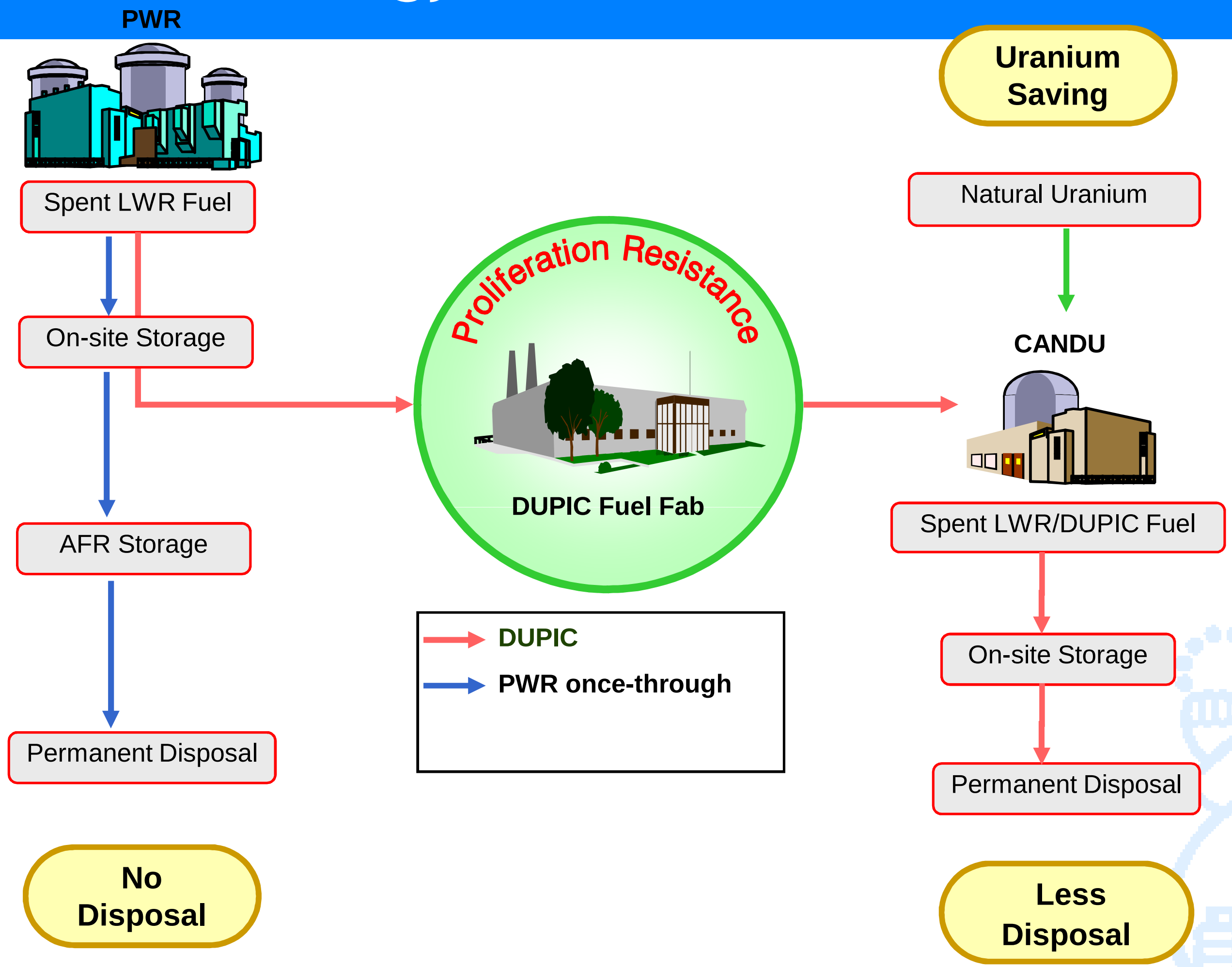
The Nuclear Fuel Cycle



Background ...

- IAEA suggests to construct and operate some regional reprocessing plant (for example in east asia region)
- Non-proliferation strategy proposed *not to separate Plutonium with Minor Actinides* during the spent fuel reprocessing
- Some countries (especially which not allowed to have any reprocessing plant and enrichment plant) should find a *best way to deal with their HLW.*

DUPIC: Direct Use of spent PWR fuel In CANDU reactors Strategy



Korea:

-Advanced NE Industry

-- Good budget

--Not allowed to have RP & EP

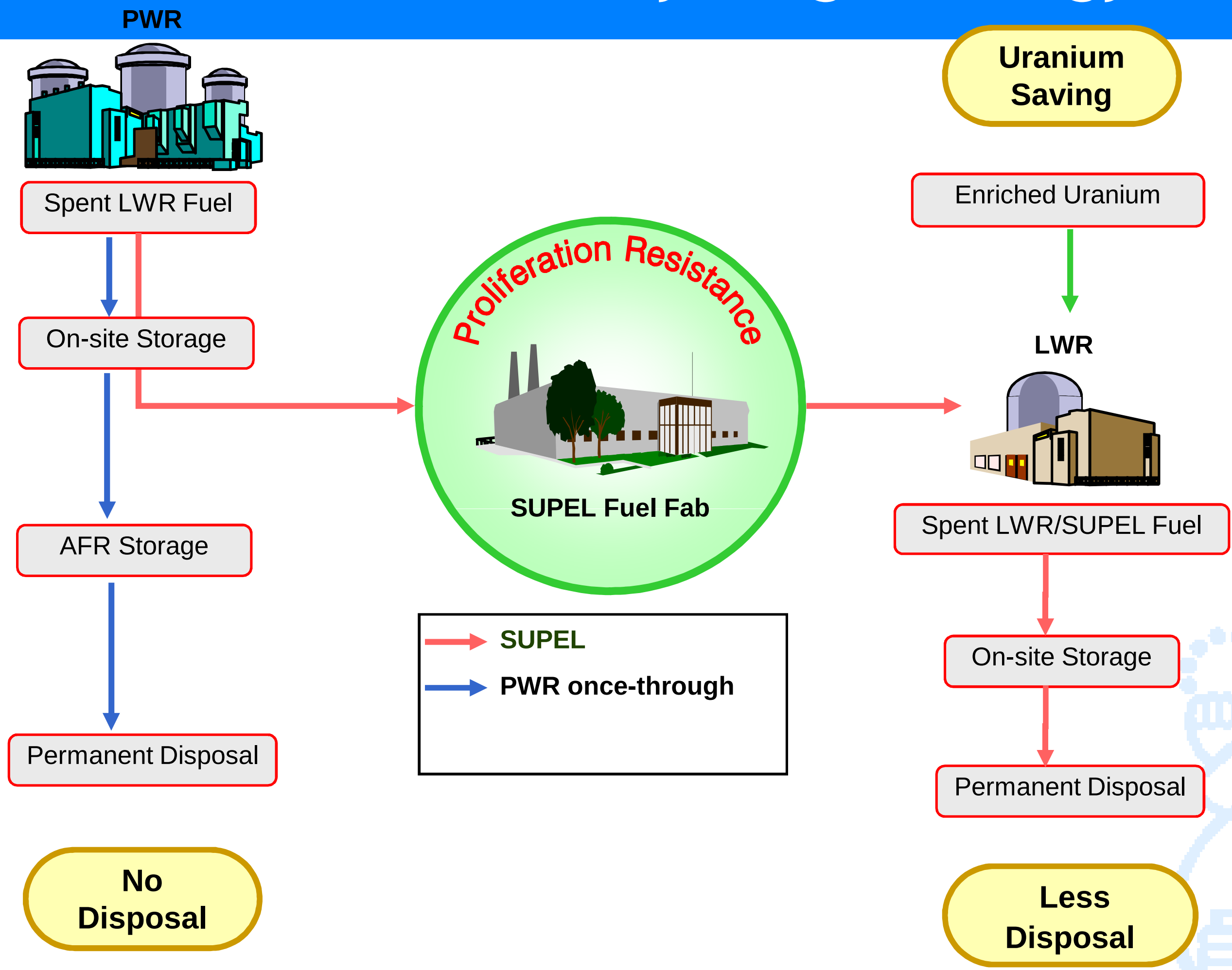
-- More than 1 type of NPP (LWR & CANDU)

* DUPIC : Direct Use of spent PWR fuel In CANDU reactors

Background …

- Country likes Indonesia (*no NE Industry, less committed, limited budget, not allowed to have RP & EP, If "go nuclear" might have only 1 type of NPP*) should has another alternative way ➔ **SUPEL: Straight Utilization of sPEnt LWR fuel in LWR** reactors scenario for Nuclear Waste Recycling Strategy
- Best NPP candidate for Indonesia either PWR or BWR.

SUPEL Scenario for Recycling Strategy



*** SUPEL : <u>S</u>traight <u>U</u>tilization of s<u>PE</u>nt LWR fuel in <u>L</u>WR reactors**

Objective

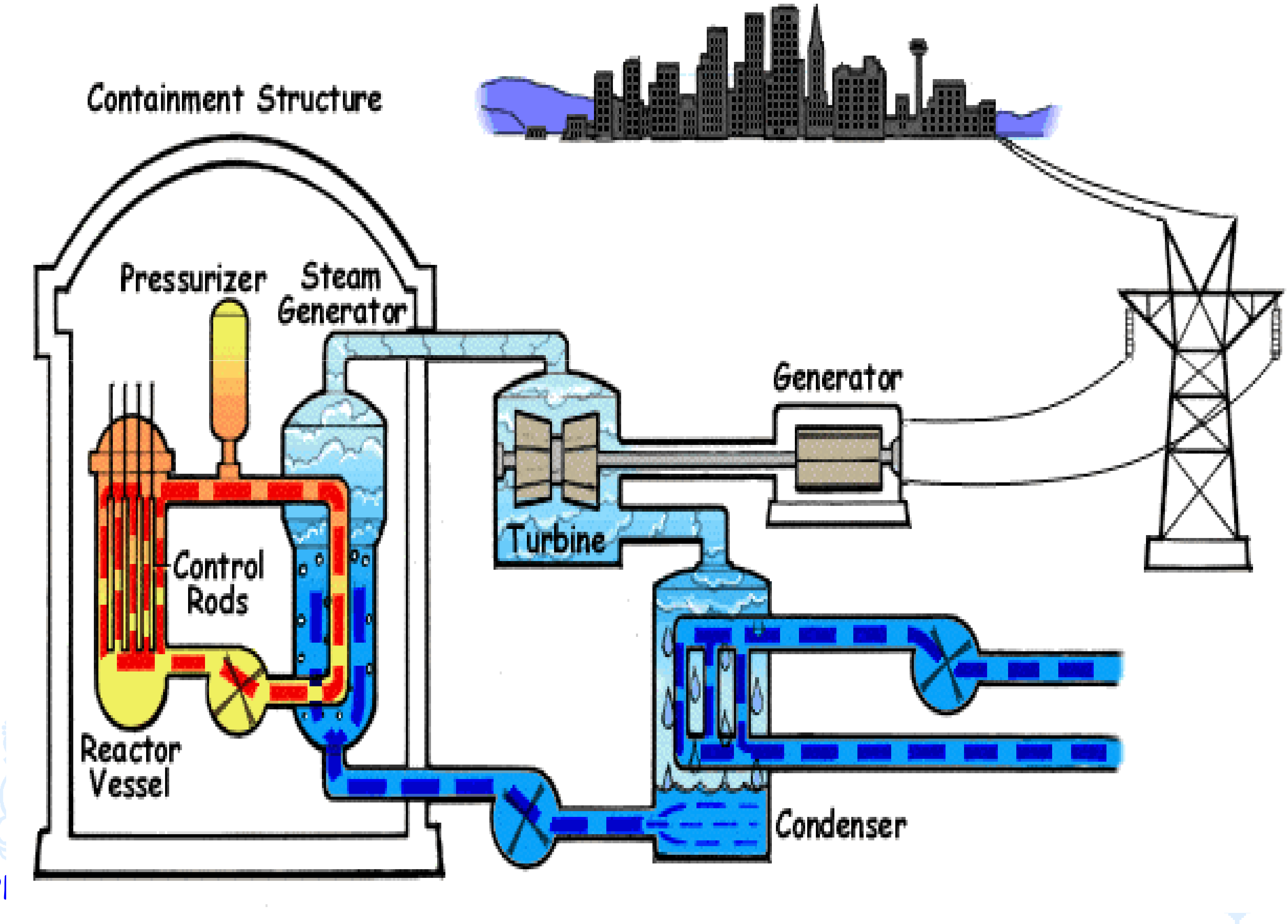
- In our previous study on SUPEL PWR, we found that the reactor can achieve it criticality when the U-235 enrichment in loaded fresh fuel is ≥ 4% and the amount of spent fuel in the core is ≤ 20%. However, the safety aspect is not evaluated yet.
- In the present report, we have performed a safety analysis of direct recycling of spent PWR fuel in PWR system, by evaluating the influence of changing moderator-to-fuel volume ratio (MFR) of PWR.

Methodology

Design parameter of studied PWR

Thermal power output	3000 MWth
Average cell power density	100 Wcm^{-3}
Fuel pellet diameter	8.0 mm
Fuel rod diameter	9.6 mm
Pin pitch	11.8 mm
Fuel type	Oxide
Cladding	Zircaloy-4
Coolant	H_2O
Moderator-to-fuel volume ratio (MFR)	0.5 – 4.0

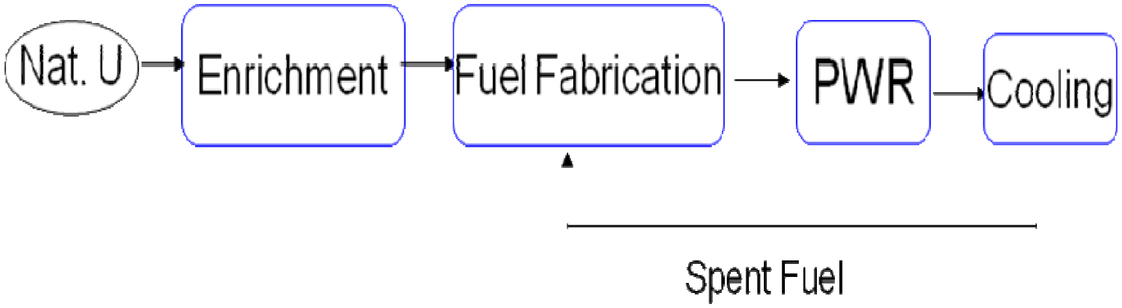
Nuclear Power Plant using Pressurized Water Reactor (PWR)



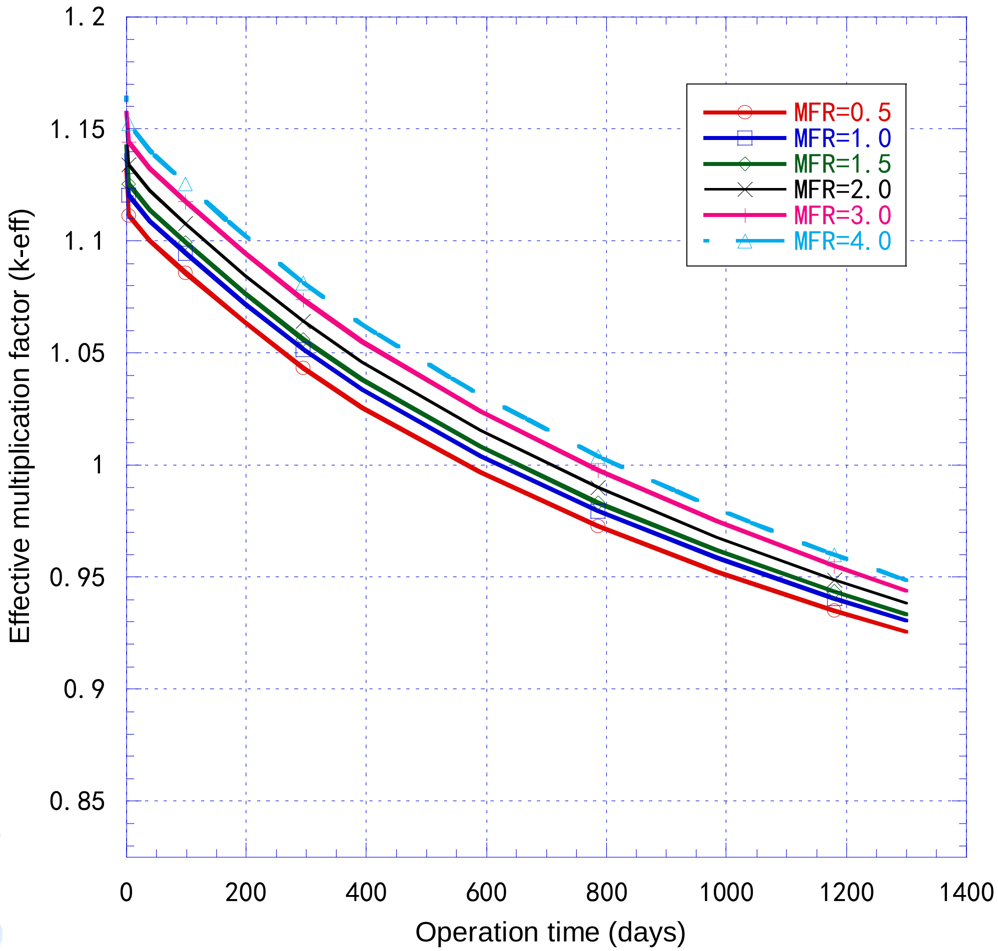
Pl

Methodology …

Diagram of SUPEL Scenario

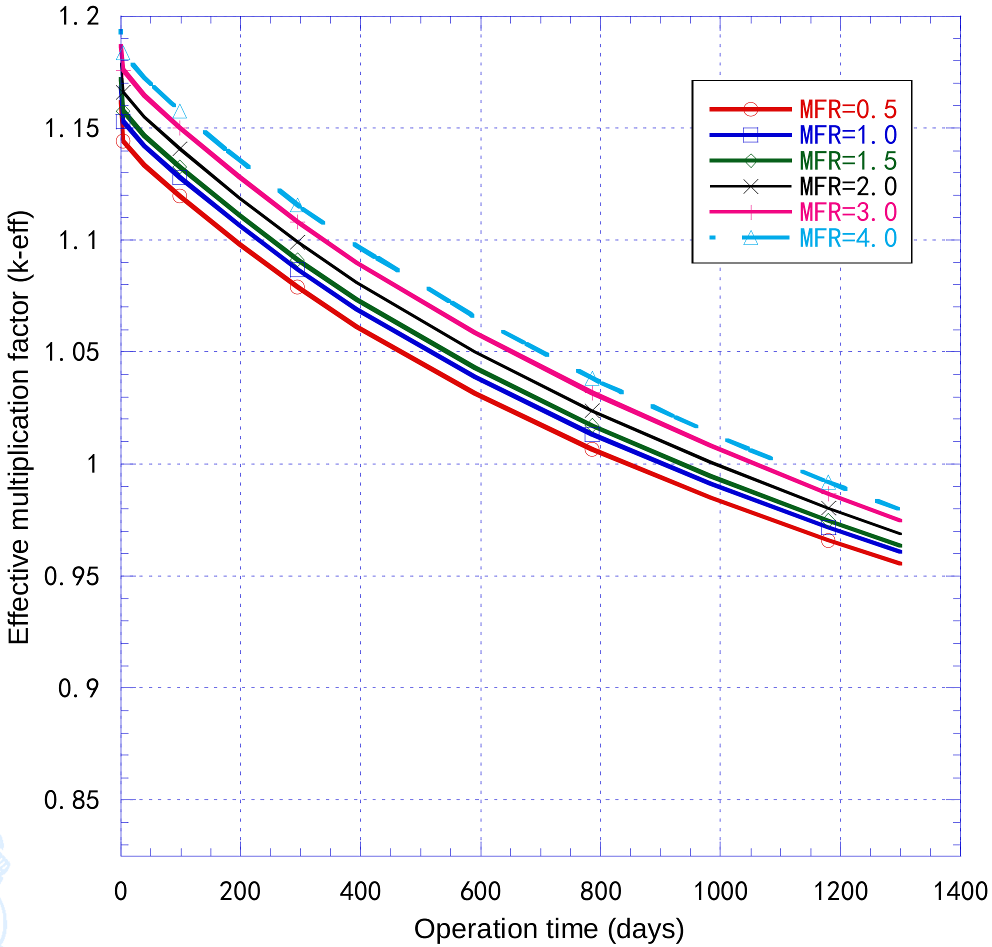


Effective multiplication factor (k-eff) of 6.0% UO_2 enrichment



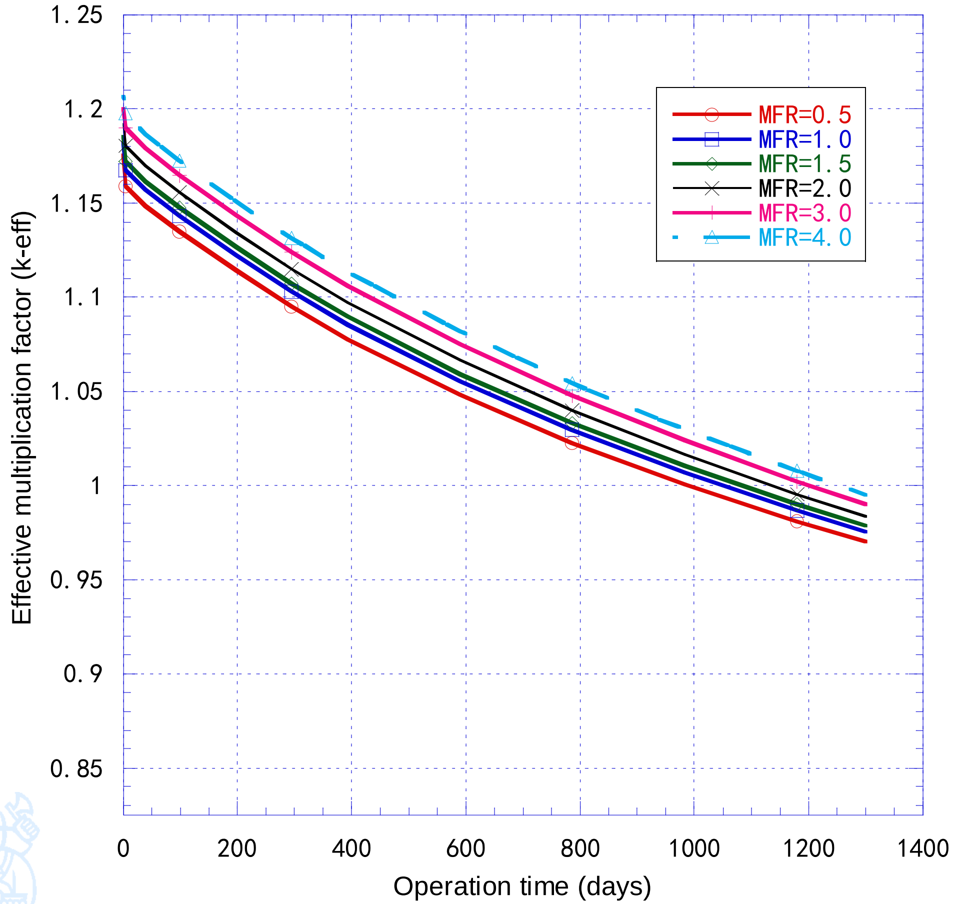
PWR can not attain its criticality condition

Effective multiplication factor (k-eff) of 6.5% UO_2 enrichment



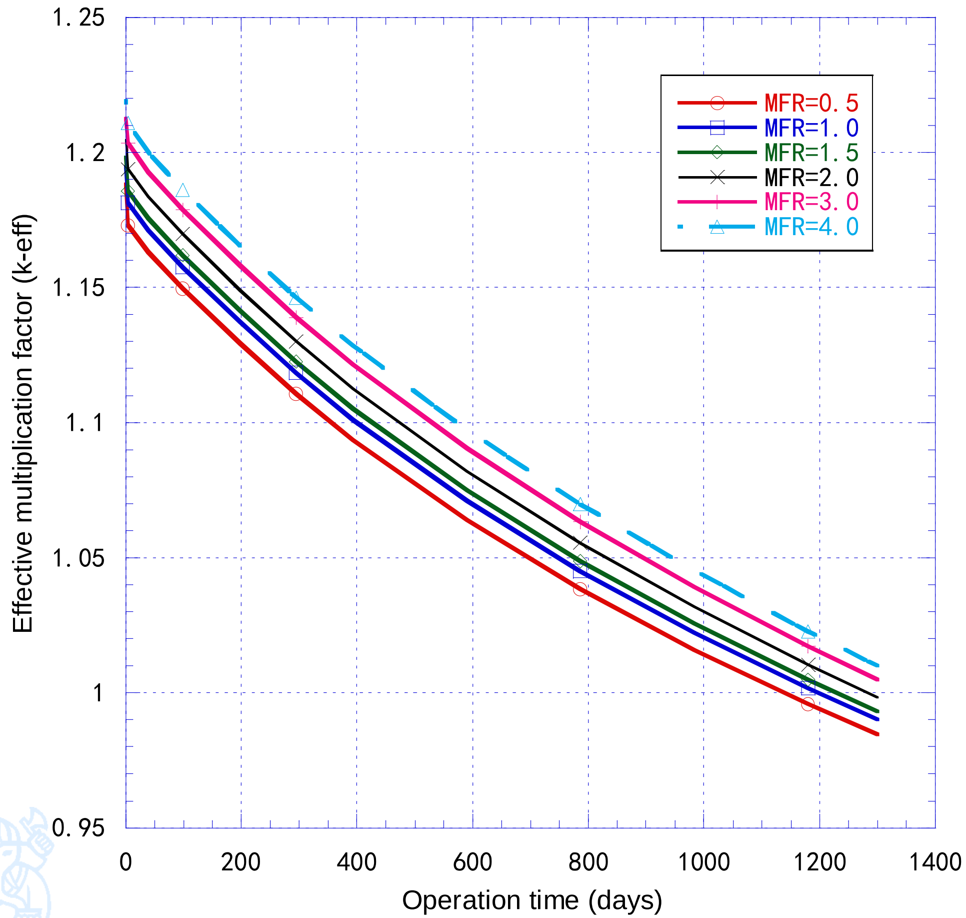
PWR can attain its criticality condition for MFR = 4.0, since k-eff > 1 after more than 2/3 of operation time (cycle length)

Effective multiplication factor (k-eff) of 7.0% UO_2 enrichment



PWR can attain its criticality condition for all MFR values, since k-eff > 1 after more than 2/3 of operation time (cycle length)

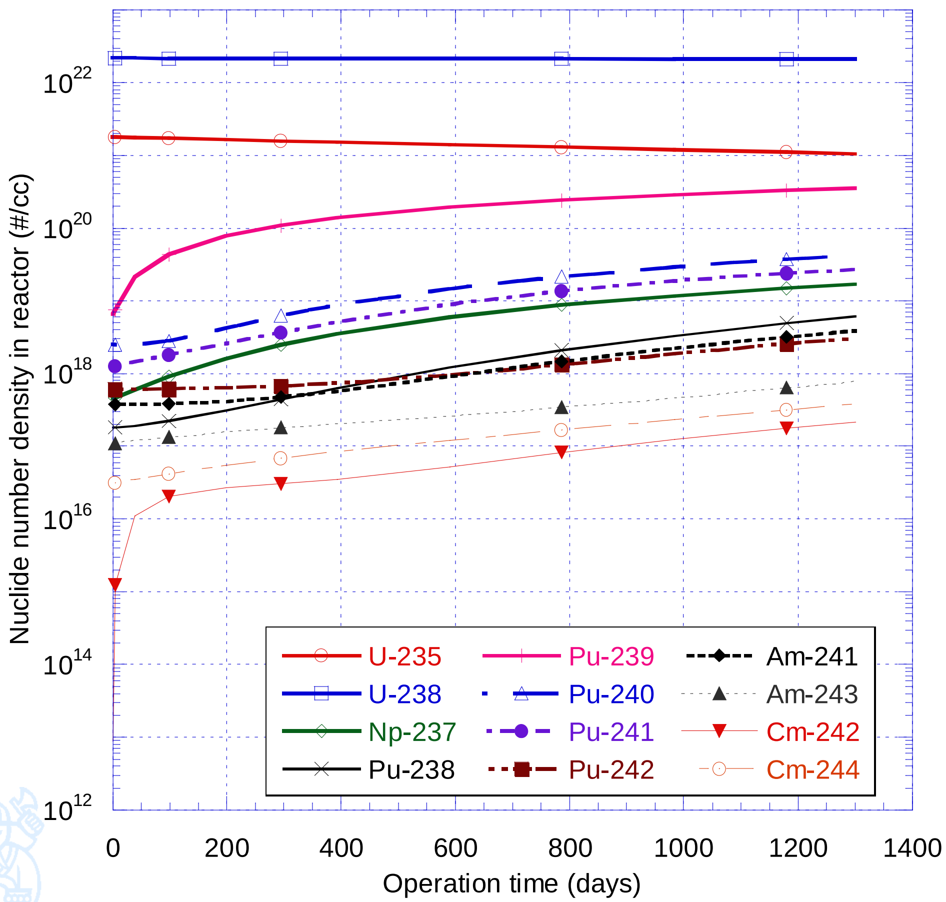
Effective multiplication factor (k-eff) of 7.5% UO_2 enrichment



1. PWR can attain its criticality condition for All MFR values, since k-eff > 1 during the whole operation time (cycle length).
2. The criticality can be achieved easier as the increasing of MFR

Since in PWR, the moderator is also the coolant material, more coolant means that cooling process becomes faster. As a consequence, the safety of the reactor becomes higher

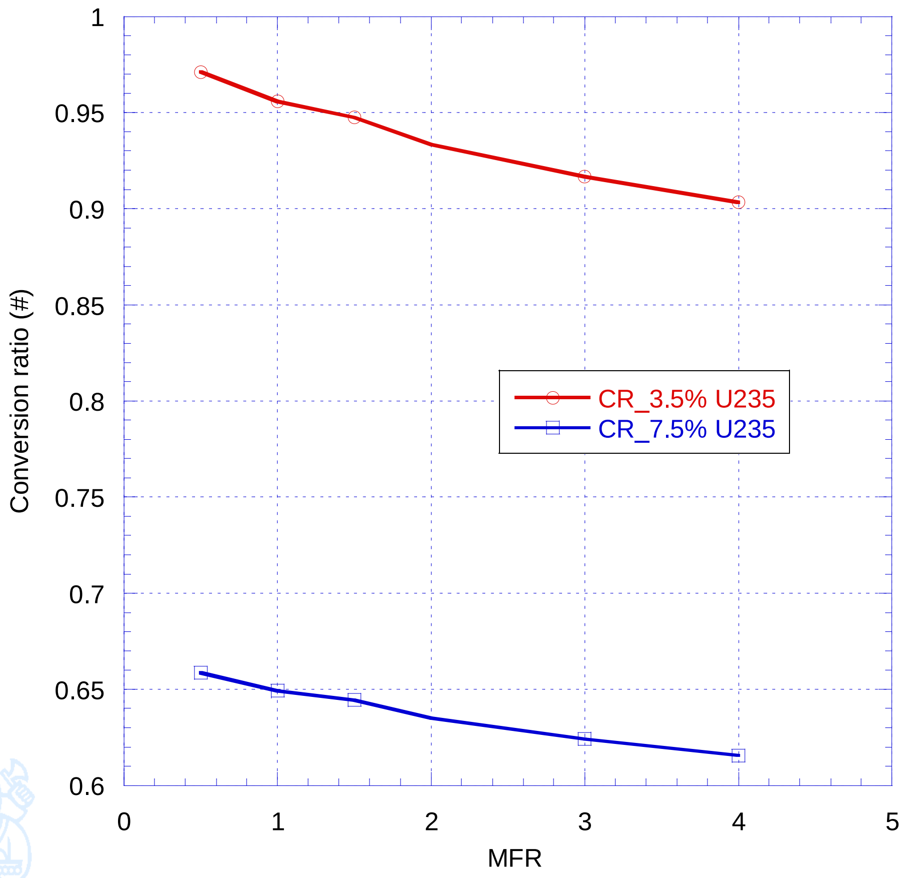
Number density of actinides for 8.0% enrichment for MFR=4.0



The number density of Pu-239, Pu-240, Pu-241, and Cm-244 significantly reduce with the augmenting of MFR.

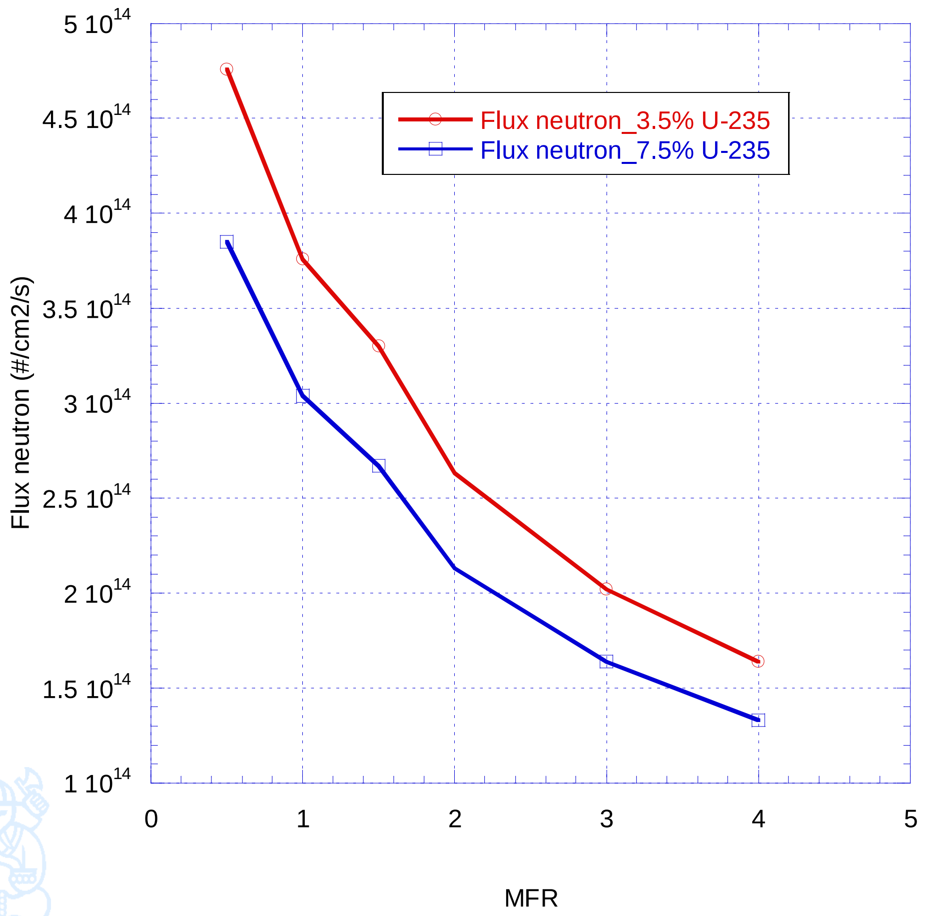
In contrast, the number density of Pu-238, Am-241, Am-243, and Cm-242 increase with the enlarging of MFR.

Conversion ratio for 3.5% and 7.5% enrichment



The conversion ratio decreases with the increasing of MFR as well as the increasing of UO_2 enrichment in loaded fresh fuel.

Neutron Flux for 3.5% and 7.5% enrichment



The neutron flux decreases with the increasing of MFR as well as the increasing of UO_2 enrichment in loaded fresh fuel.

Conclusion

- Preliminary study on safety analysis of direct recycling of PWR spent fuel to support SUPEL scenario has been carried out.
- The reactor can achieve it criticality for as a minimum 6.5 a% of U-235 enrichment in the loaded fresh fuel with the fraction of spent fuel in the core is 5.0 %.
- The criticality can be achieved easier as the increasing of MFR. Since in PWR, the moderator is also the coolant material, more coolant means that cooling process becomes faster. As a consequence, the safety of the reactor becomes higher.


Arigatou Gozaimasu
Terima kasih
Thank you