Plutonium Management in Small Nuclear Country

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International Conference on Opportunities and Challenges for Water Cooled Reactors in the 21st Century

Vienna

October 27-30, 2009

Introduction

Small nuclear country

- **evolution of existing nuclear technology rather than strong participation on revolution solution development**
- **future introduction of FR should not be endangered**

Plutonium surplus (1/3)

Nuclide	Mass [kg]
Sum of uranium	5.90547E+05
Sum of neptunium	3.33015E+02
Sum of plutonium	5.62261E+03
Sum of americium	8.51769E+02
Sum of curium	2.78415E+00
Sum of californium	1.02119E-13
Sum of actinides	5.97357E+05
Sum of fission products	1.54463E+03
Total	5.98902E+05

Element masses in the spent fuel of NPP V1 Bohunice

Plutonium surplus (2/3)

Plutonium balance

- ❑ NPP V1 Bohunice – 55 reactor-years > 5,6 t of Pu
- ❑ NPP V2 Bohunice and NPP Mochovce (2 units) – 65 reactor-years > min. 6 t of Pu
- ❑ min. 11 t of Pu is available
- ❑ SUPER PHENIX needs for the start-up less than 9 t of Pu

Mass of abundant Pu

- ❖ is min. 2 t even if FR reactor is started in Slovakia
- ❖ is growing instantly – 4 units in operation, 2 more from 2013, 1 or 2 more later on

Plutonium surplus (3/3)

Locality	No	Type	Remark
Bohunice	2	VVER-440 - 213	-
Mochovce	2	VVER-440 - 213	-
Mochovce	2	VVER-440 - 213+	Under construction
Bohunice	?	?	Under preparation

Nuclear units in Slovakia

Reducing cycles (1/7)

Alternative partially closed fuel cycles:

- ✓ with inert matrix fuel – IMF
- ✓ with Th and Pu without spent Th fuel reprocessing - PuThOX
- ✓ with Th and Pu and with spent Th fuel reprocessing - UPuThOX

Reference fuel cycles:

- classical open fuel cycle – UOX
- classical MOX

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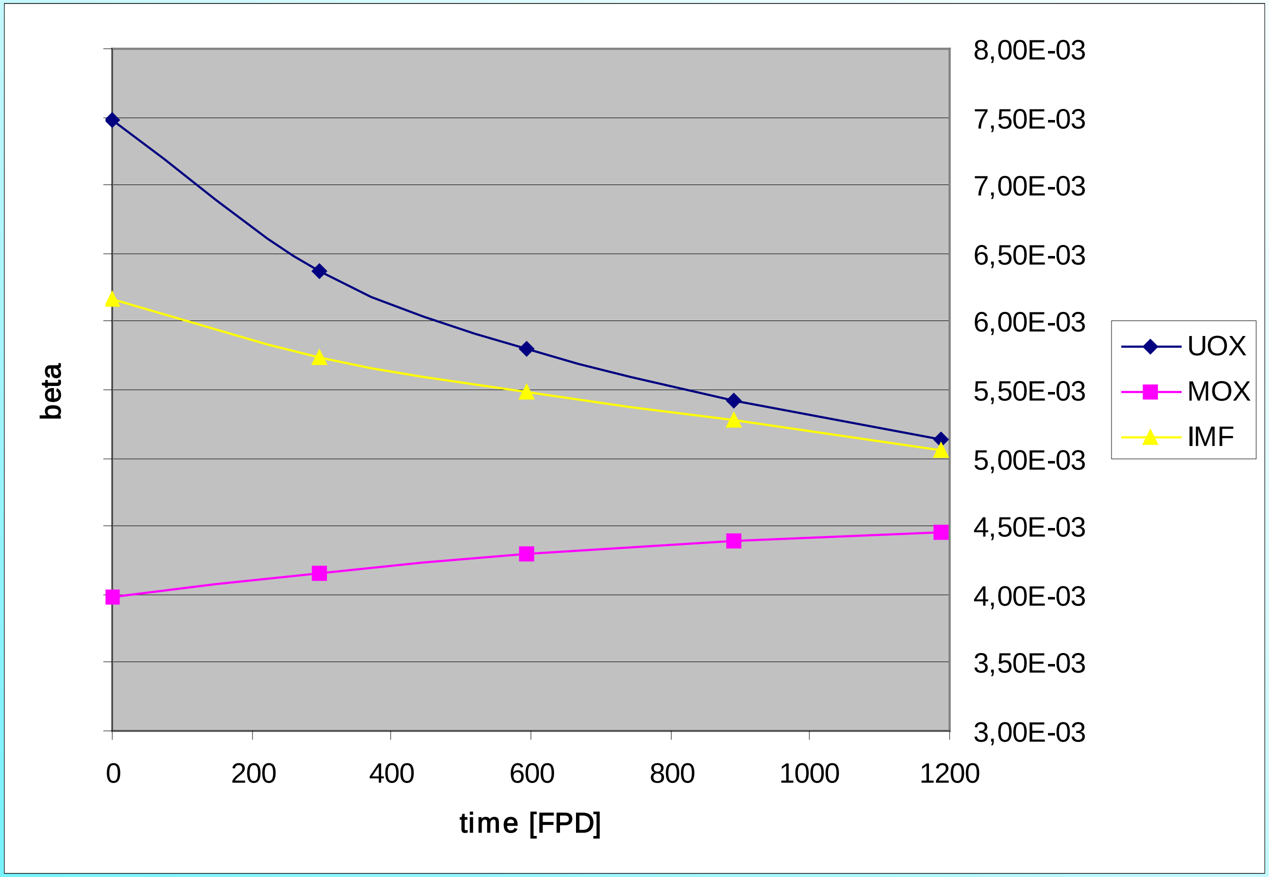
Reducing cycles (1/7)

reactivity coefficients	fuel type		
	UOX	MOX	IMF
dro/dcb (%/g/kgH_2O)	-6.5295	-3.3789	-5.2093
dro/dTm (%/deg)	-2.9950E-04	-6.8460E-04	-8.4776E-04
dro/d(Tm+den) (%/deg)	-1.6594E-02	-3.7049E-02	-2.3861E-02
dro/dTf (%/deg)	-1.8748E-03	-2.8448E-03	-1.9074E-03

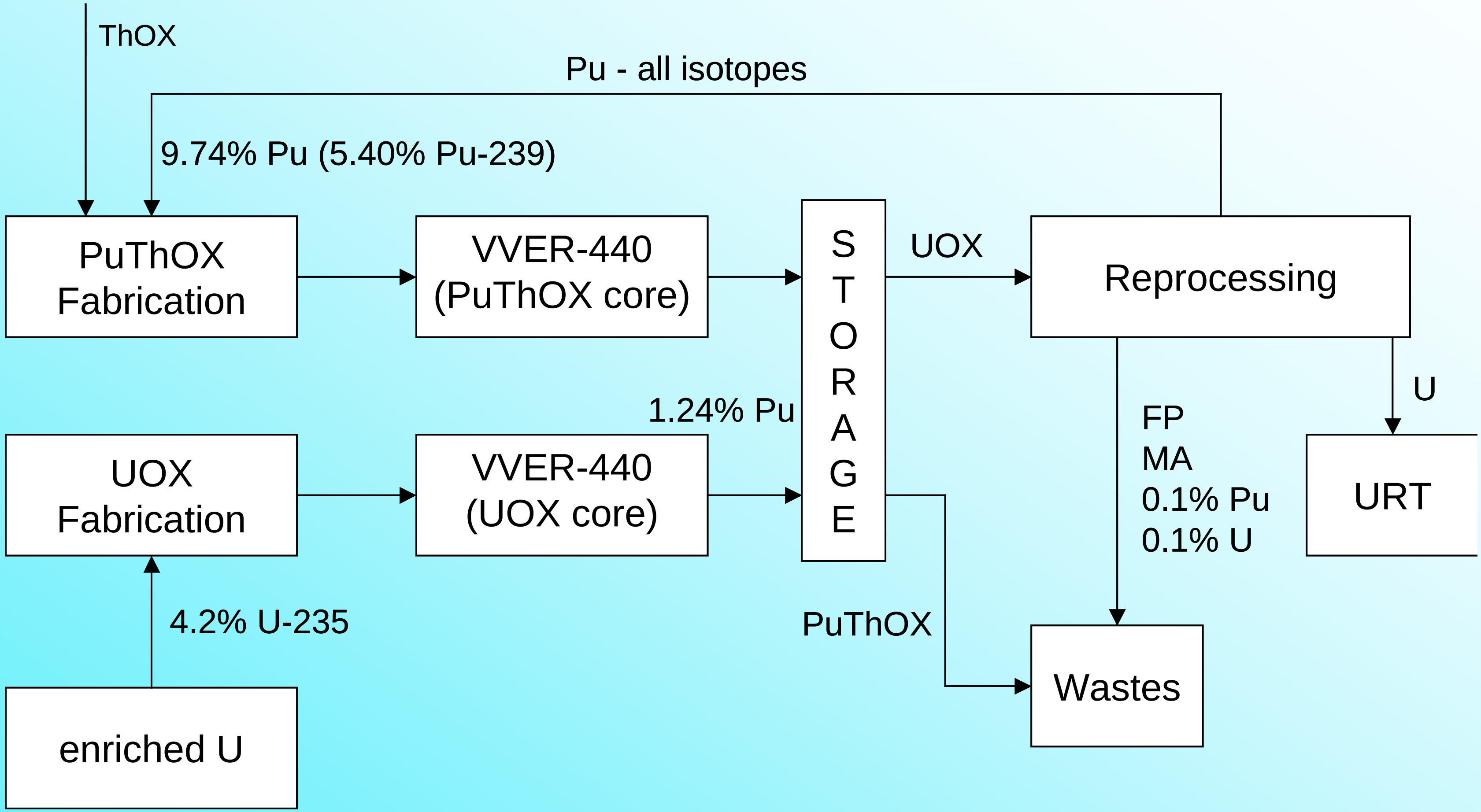
Comparison of reactivity coefficients

Reducing cycles (2/7)



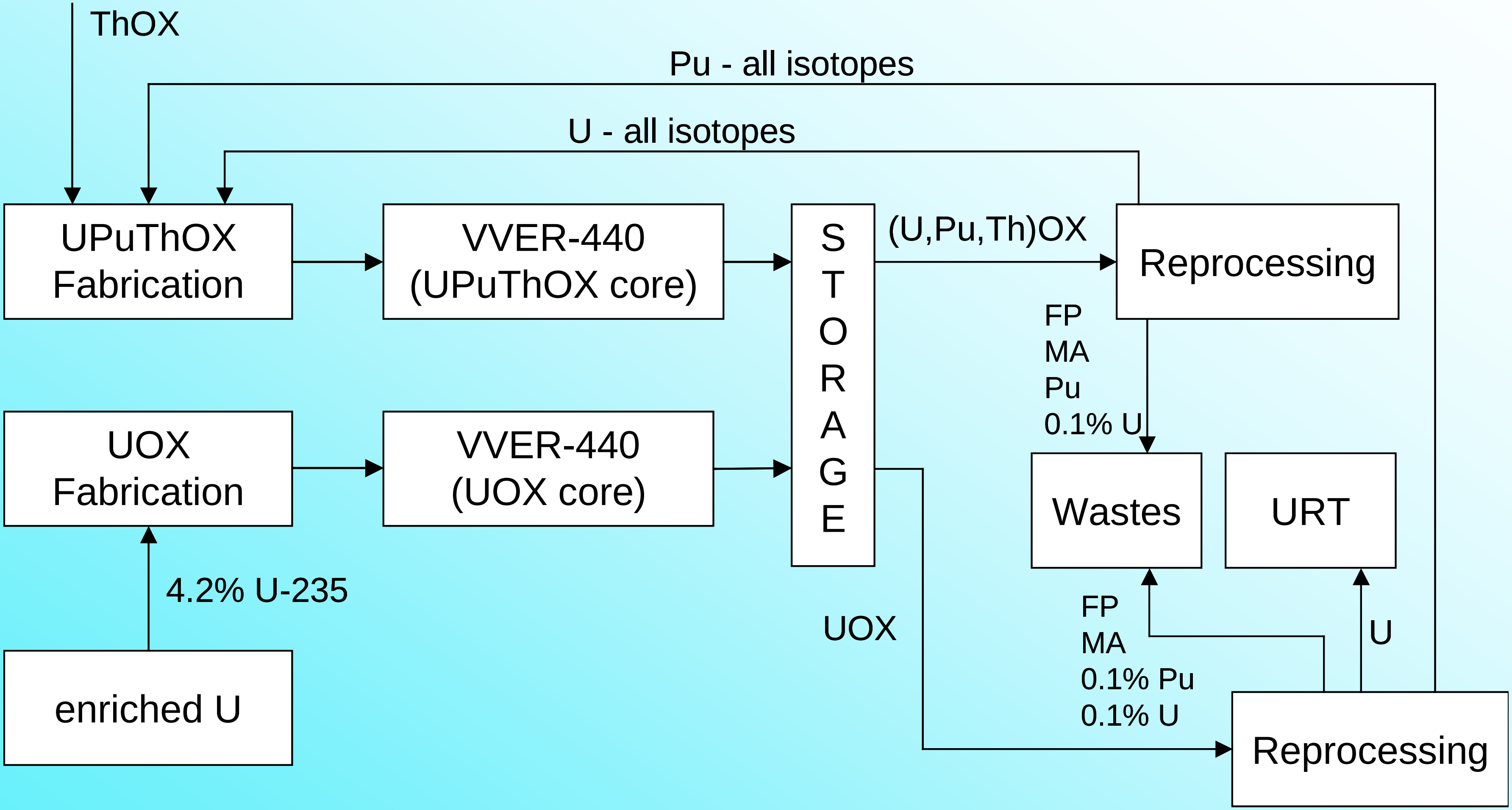
Delayed neutron fraction comparison

Reducing cycles (3/7)



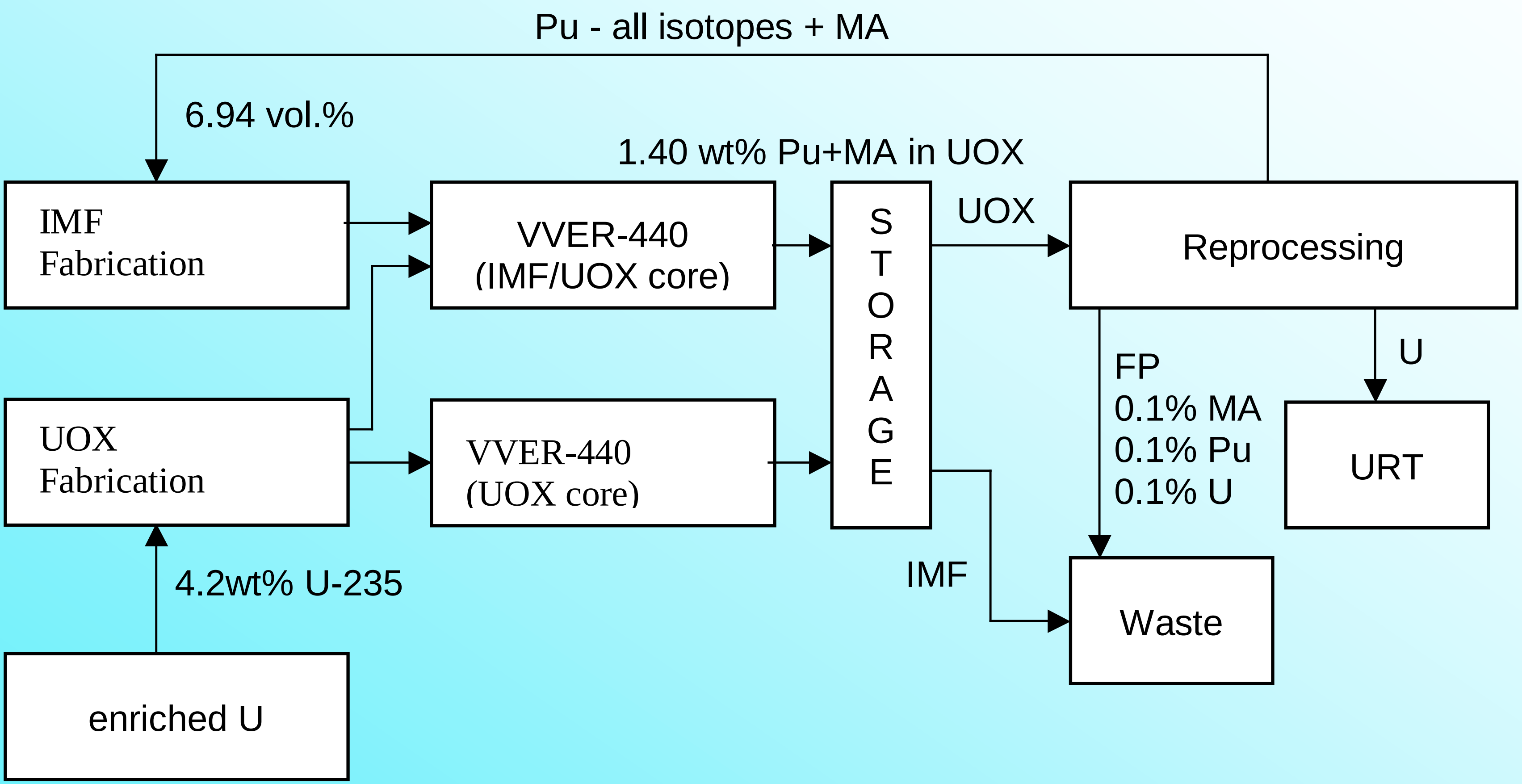
PuThOX fuel cycle (7.9 of UOX cores needed)

Reducing cycles (4/7)



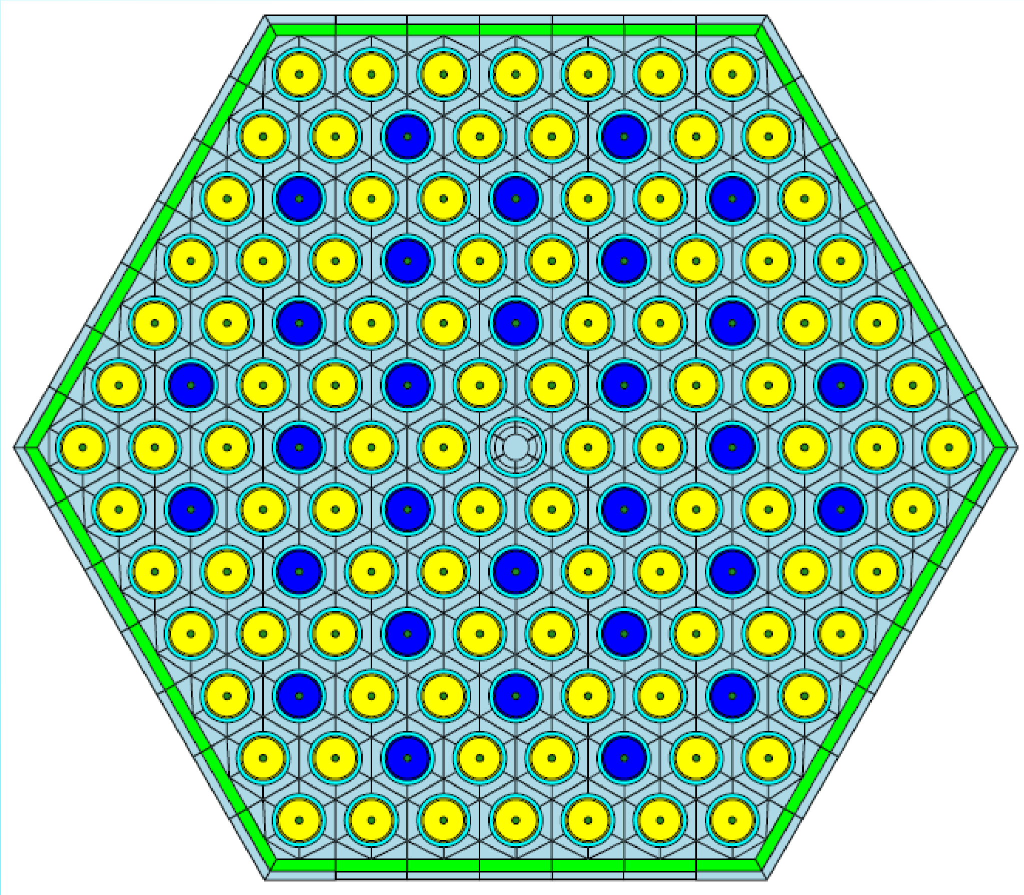
UPuThOX fuel cycle (3.4 of UOX cores needed)

Reducing cycles (5/7)



IMF fuel cycle (self-cleaning)

Reducing cycles (6/7)



Model of combined VVER-440 assembly

Reducing cycles (7/7)

	UOX	PuThOX	UPuThOX	IMF
Pu initial (kg/tHM)	0	97.38	41.42	14.05
Pu in spent fuel after 5y cooling (kg/tHM)	12.37	51.39	15.25	3.21
MA in spent fuel after 5y cooling (kg/tHM)	1.48	6.15	3.39	1.22
Pu transmutation rate (%)	0	47.22	63.18	77.08
Pu transmutation rate (kg/TWhe)	0	13.22	17.64	7.32
Pu generation rate (kg/TWhe)	32.2	15.5	10.5	6.2
MA genetration rate (kg/TWhe)	3.8	3.3	2.9	2.7

Potential of Pu transmutation

Reducing cycles (7/7)

Key effects demonstrated:

- ❑ important exploitation parameters are not distorted at IMF cycle
- ❑ electricity production in LWRs with alternative cycles is connected with smaller generation of Pu and MA
- ❑ the best in this way is cycle with IMF

Conclusion (1/2)

Pu management

- Pu mass in SNF is sufficient for FR start-up in Slovakia
- Pu smaller production can be reached by partially closed fuel cycle with IMF or Th
- remaining Pu and MA can be transmuted later in FRs or MSRs

Conclusion (2/2)

Positive effects of IMF and Th application

- no expensive and time-consuming unit reconstruction
- simplified construction of deep repository
- reduction of nonproliferation problems
- partial replacement of natural uranium by reprocessed plutonium