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Comparison of 16 Reactors Neutronic Performance in Closed Th-U and U-Pu Cycles

Summary / Objectives:

Just as in all other industries, sustainability is vital to nuclear energy production. **Recycling of nuclear fuel contributes to the environmental and social pillars of that sustainability** because it simultaneously improves natural resources utilization and waste minimization. This webinar provides additional insight to the consequences of repetitive fuel recycling and compares selected reactors based on their **neutronics performance in the closed Th-U and U-Pu cycles**. Because the closed fuel cycle has been discussed in several previous GIF webinars, this presentation focuses on less common perspectives. The closed fuel cycle will be presented as a **Bateman equation eigenstate**. In several cases, the eigenstate will be achieved by irradiation of subcritical fuels. It will be shown that all reactors in the respective fuel cycle have, by chance, **the same average neutron production per fission**. Hence, the usual measure η-2 will be replaced by fission probability discussion. Although the Bateman equation eigenstate in this comparative study is reached without fission products, their role in the closed cycle will be addressed.

Meet the Presenter:

Dr. Jiri Krepel is a senior scientist in Advanced Nuclear Systems group of Laboratory for Scientific Computing at **Paul Scherrer Institute (PSI) in Switzerland**. He earned his PhD in 2006 at the Czech Technical University (CTU) Prague / Helmholtz-Zentrum Dresden-Rossendorf for his thesis entitled "Dynamics of Molten Salt Reactors (MSR)." At PSI, he is responsible for **fuel cycle analysis and related safety parameters of Gen IV reactors**. Dr. Krepel is the coordinator of the PSI MSR research and represents Switzerland at the GIF MSR project. He has experience in the neutronics of liquid-metal and gas-cooled fast reactors and in neutronics and transient analysis of thermal and fast MSRs. He has participated in the following national and international R&D programs: MOST, ELSY, EUROTRANS, GCFR, ESFR, GoFastR, LEADER, PINE, ESNII+, SAMOFAR, ESFR-SMART, and SAMOSAFER.

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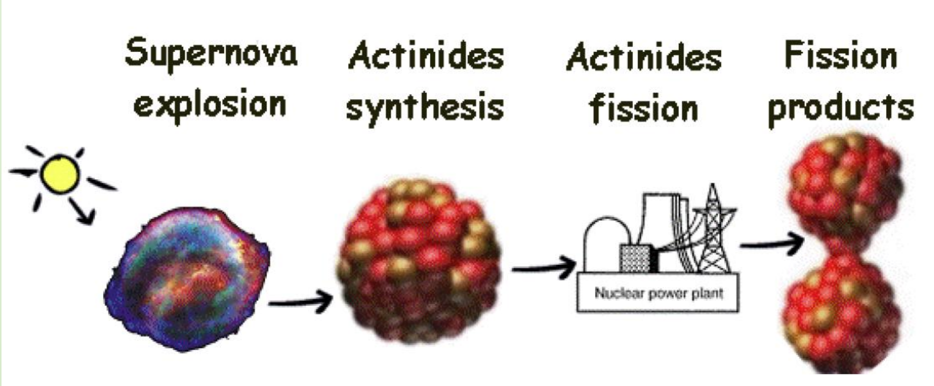
What is Closed Fuel Cycle?:

Primordial actinide reserves, as a Supernova product, as a fuel for the nuclear energy, are not renewable.



Origin of the universe

Technological use of Nuclear: Open cycle

Nuclear Closed cycle: Closed for Actinides.

Sustainability:

I. High resources utilization, we should fission at best all primordial actinides.

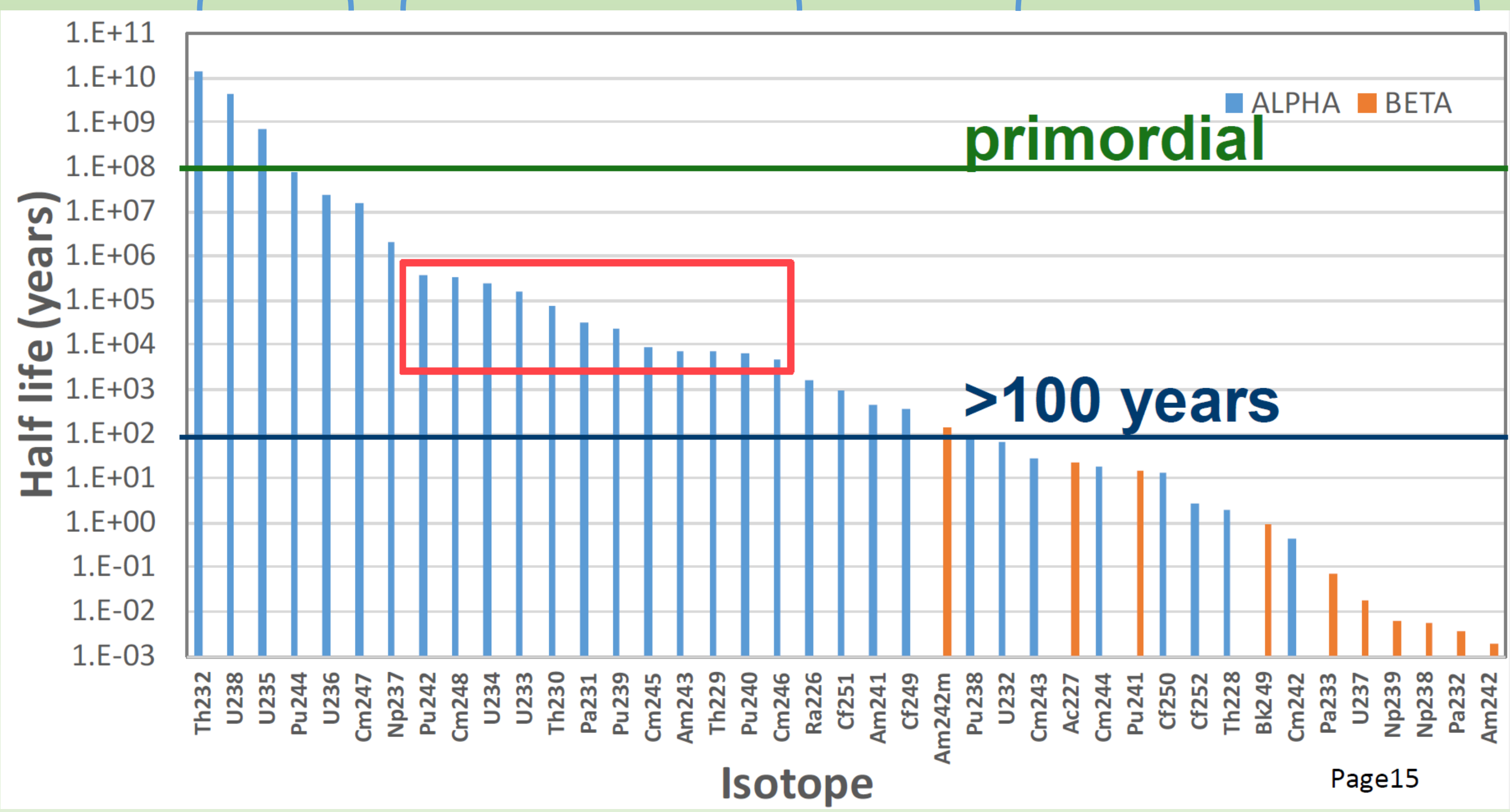
II. Waste minimization, we should minimize synthetic actinides amount in the waste.

I. Higher burnup in **open** fuel **cycle**
II. Actinides **recycling** in **closed cycle**

Primordial actinides: Long half-lives

Synthetic actinides: too long to disappear swiftly once originated

Short term actinides: decaying in chains



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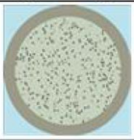
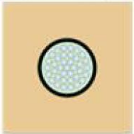
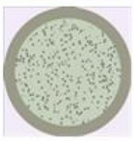
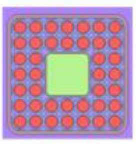
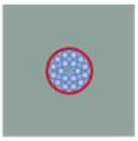
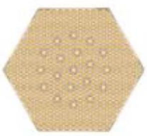
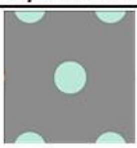
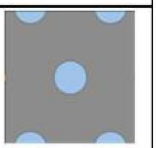
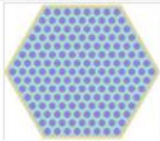
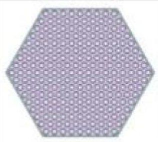
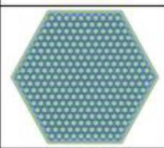
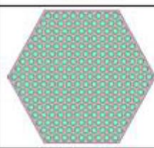
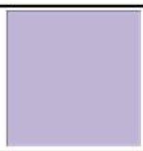
Performance of 16 reactors in equilibrium for U-Pu or Th-U cycles:

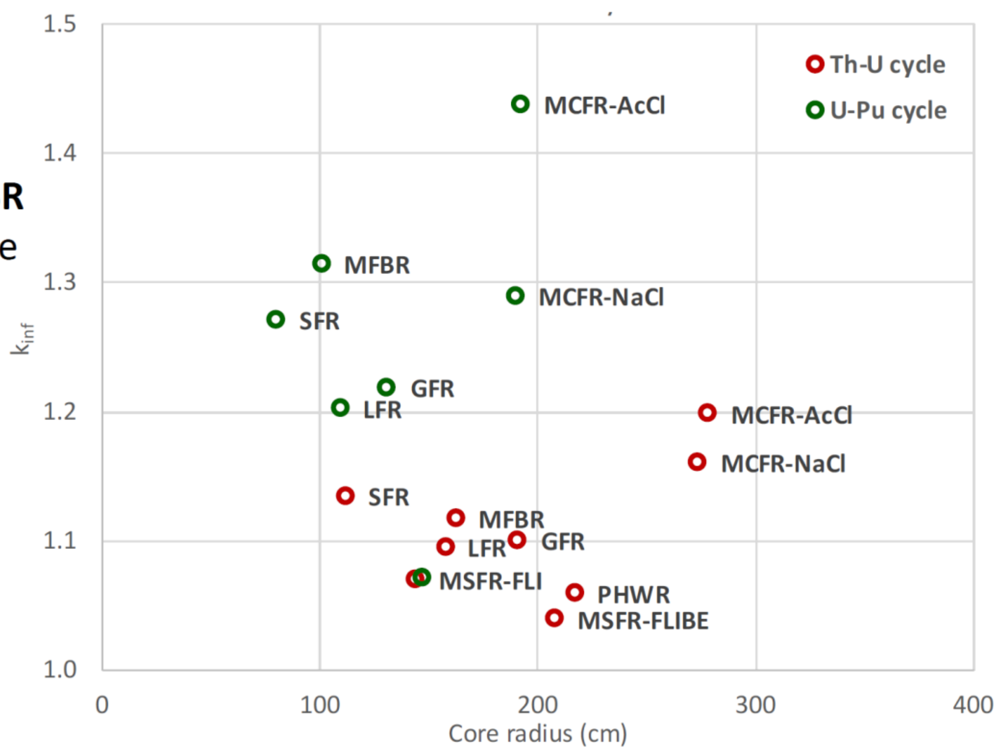
Neutronics comparison based on Bateman matrix equilibrium from Equilibrium multiplication factors, Core radius estimates, Actinides losses by recycling, etc.

Solid fuel thermal reactors			
Reactor name (and label)	**Lattice geometry**	**Name and short name**	**Lattice geometry**
Fluoride high temperature reactor PB-AHTR (**FHR**)		Pressurized heavy water reactor (**PHWR**)	
High temperature reactor (**HTR**)		High performance light water reactor (**HPLWR**)	
Reaktor balshoi moshnosti kanalnyj (**RBMK**)		Light water reactor VVER-1000 (**LWR**)	
Liquid fuel thermal reactors			
Thermal MSR fueled by LiF-BeF_2-AcF_4 (**MSR-FLIBE**)		Thermal MSR fueled by LiF-AcF_4 (**MSR-FLI**)	

Solid fuel fast reactors			
Reactor name (and label)	**Lattice geometry**	**Name and short name**	**Lattice geometry**
European lead system (**LFR**)		Gas cooled fast reactor (**GFR**)	
European sodium fast reactor (**SFR**)		Metal fueled fast breeder reactor (**MFBR**)	
Liquid fuel fast reactors			
Molten salt fast reactor fueled by LiF-BeF_2-AcF_4 (**MSFR-FLIBE**)		Molten salt fast reactor fueled by NaCl-$AcCl_4$ (**MCFR-NaCl**)	
Molten salt fast reactor fueled by LiF-AcF_4 (**MSFR-FLI**)		Molten salt fast reactor fueled by $AcCl_4$ (**MCFR-AcCl**)	

Core radius estimate: Th-U cycle X U-Pu cycle

- By all other fast reactors **U-Pu** cycle provides **smaller cores**.
- **MSFR-FLI** is the **smallest MSR** core and it has the same core size for both cycles. (**very soft fast spectrum**)
- **SFR** is the **most compact** bare iso-breeding core in both cycles.
- **MCFR** is the **biggest** bare iso-breeding core in both cycles.



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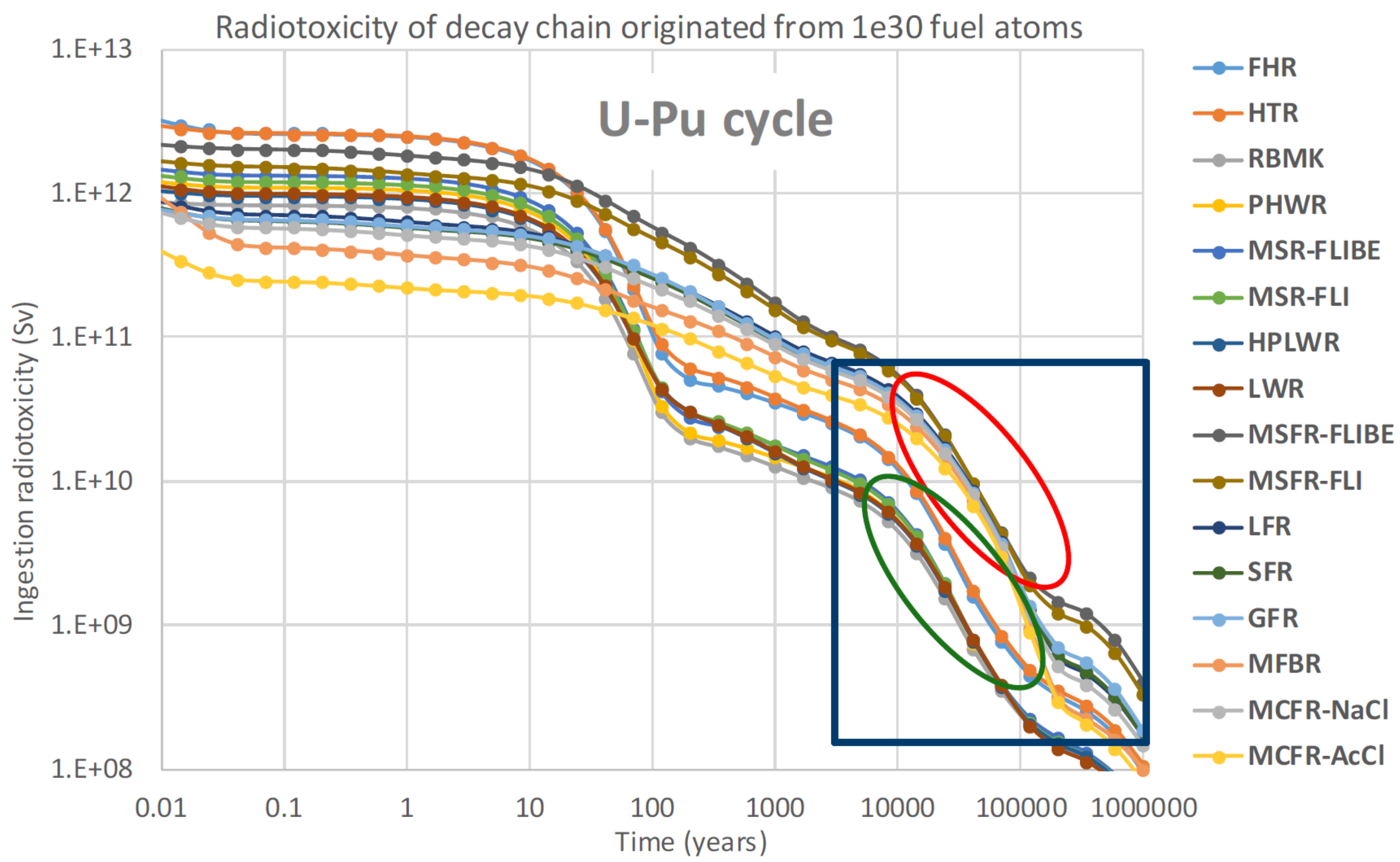
Performance of 16 reactors in equilibrium for U-Pu or Th-U cycles:



Summary of neutronics comparison

	U-Pu cycle	Th-U cycle
Reserves of ^{238}U and ^{232}Th:	no argument for preference, we are lucky to have both.	
Features of ^{238}U and ^{232}Th:	slightly better *(direct fission, etc.)*	
Features of ^{239}Pu and ^{233}U:	higher ν, higher capture	lower ν, lower capture
Thermal spectrum capability:	no	yes
Fast spectrum capability:	yes	yes
Breed and burn capability:	yes	no
Radiotoxicity at equal conditions:	initially higher	lower
Core size for fast reactors:	smaller	bigger
Core size in fluoride MSFR:	slightly bigger	smaller
Initial fuel for transition to eql.:	LEU or RG_Pu	RG_Pu or LEU in mixed cycle