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Transmutation in ASTRID

"FR13 – Technical Session 6.4"

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OUTLINE

Transmutation in
Advanced Sodium Technological Reactor for Industrial Demonstration

- Objectives of ASTRID
- Concepts of transmutation
- Core design
- Transmutation of Minor Actinides (MA)
- Summary

The ASTRID Objectives

➔Technological Demonstrator for Sodium Fast Reactor

(*could be a step before a First Of A Kind)*

➔Integrating French and International SFRs feedback

➔A GEN IV system

Safety :
- Level at least equivalent to GEN III systems
- Progress on Na reactors specificities
- Integrating *FUKUSHIMA accident feedback*

Operability :
- Load factor of 80% or more after first “learning” years
- Significant progress concerning In Service Inspection & Repair (ISIR)

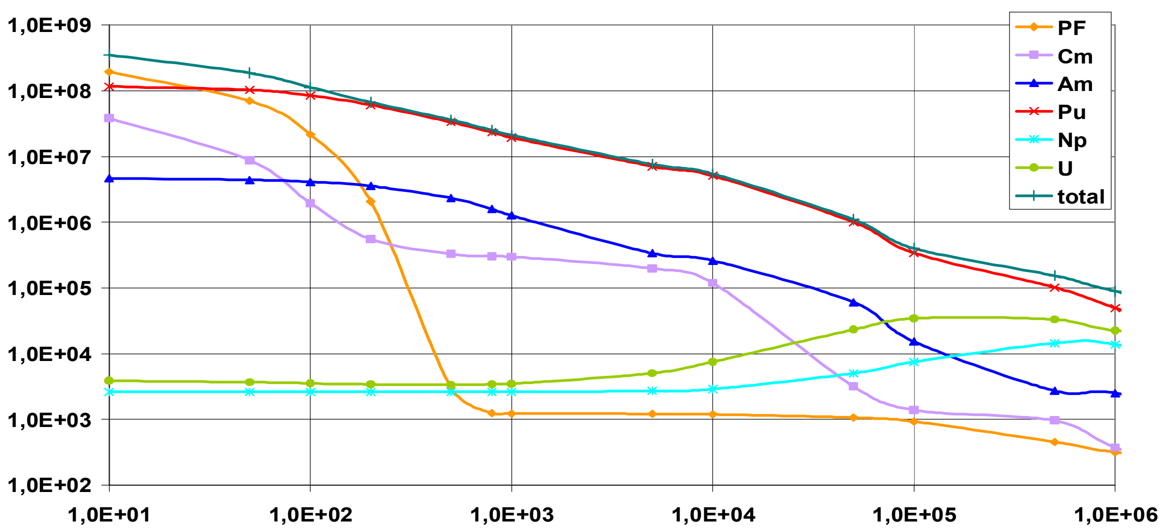
Ultimate wastes transmutation :
- Realization of demonstrations on minor actinides transmutation according to June 28, 2006 French Act on Wastes Management

A mastered investment cost

➔Irradiation services and options test

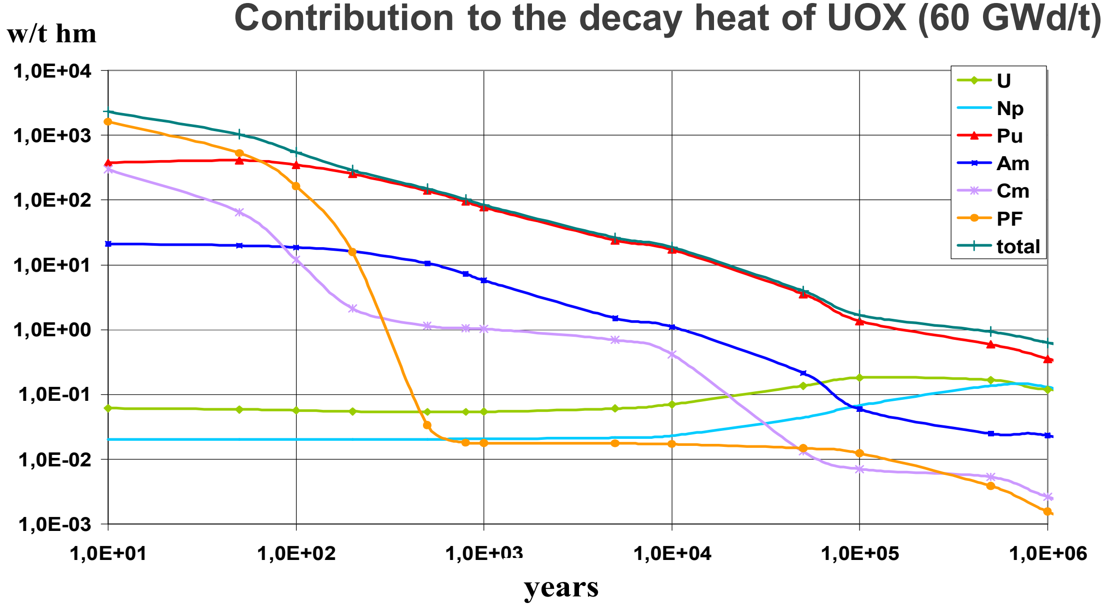
4th Generation Systems - *Transmutation*

Contribution to the radiotoxicity of UOX (60 GWd/t)



years

Contribution to the decay heat of UOX (60 GWd/t)



Spent Fuel decay heat and Radiotoxixty for long term :

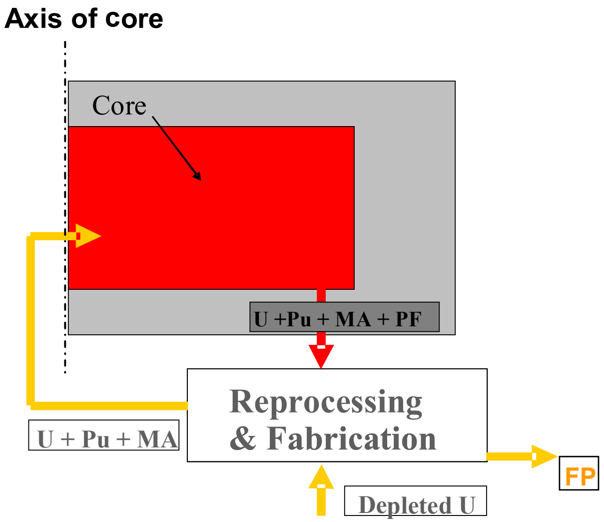
Pu > Am > Cm > U > Np

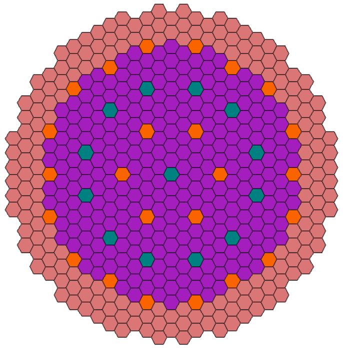
➔Reduction of :

- the risk
- the footprint of the storage

Transmutation Concepts

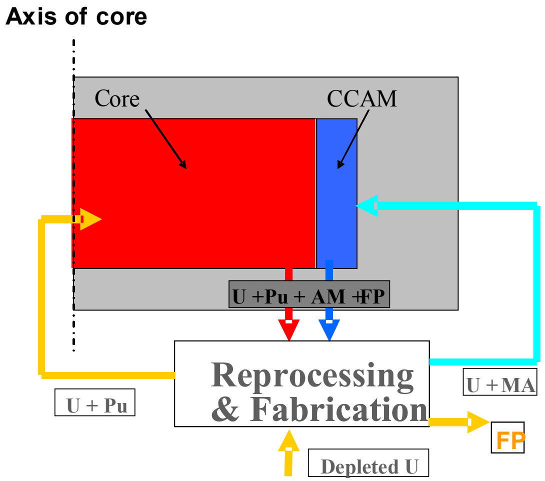
Homogeneous mode

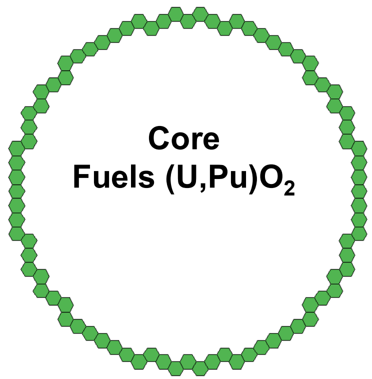




Fuels (U,Pu,MA)O_2

Heterogeneous mode





Minor-Actinides-Bearing-Blankets (MABB) (U, MA)O_2

Global objectives for the ASTRID core

- Innovative SFR core representative of technological options and performances of the future SFR industrial cores :

  - Improved safety : in particular, increased prevention of the core fusion accident and minimized significant mechanical energy release in case of core fusion

  - Performance : increased fuel cycle length and high burn up

  - Resources economy: flexibility for breeding

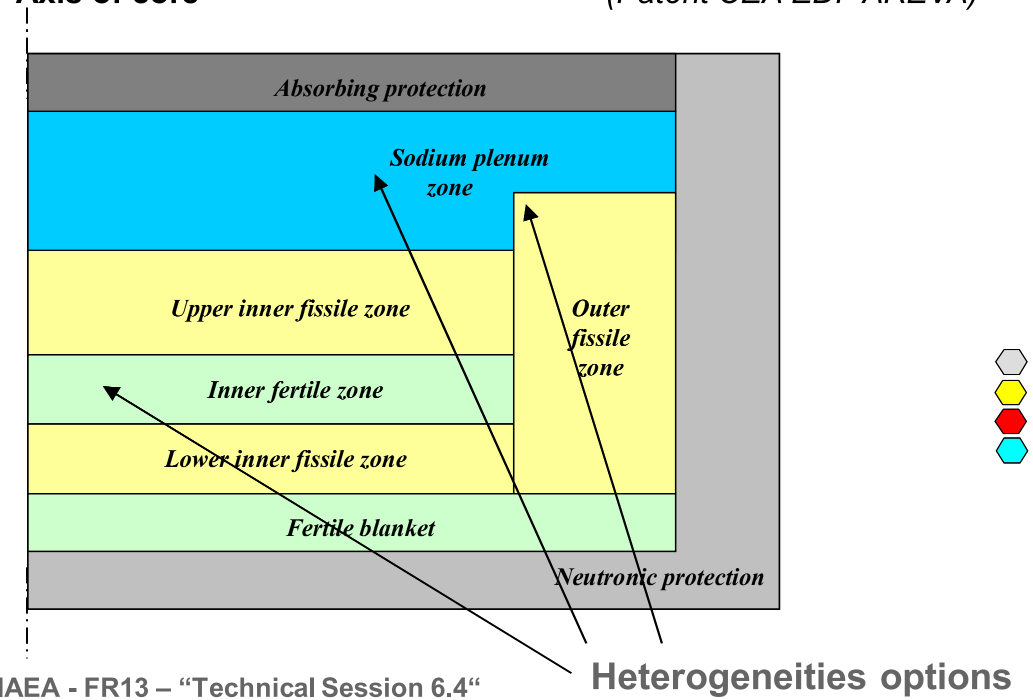
- Capability for minor actinides transmutation

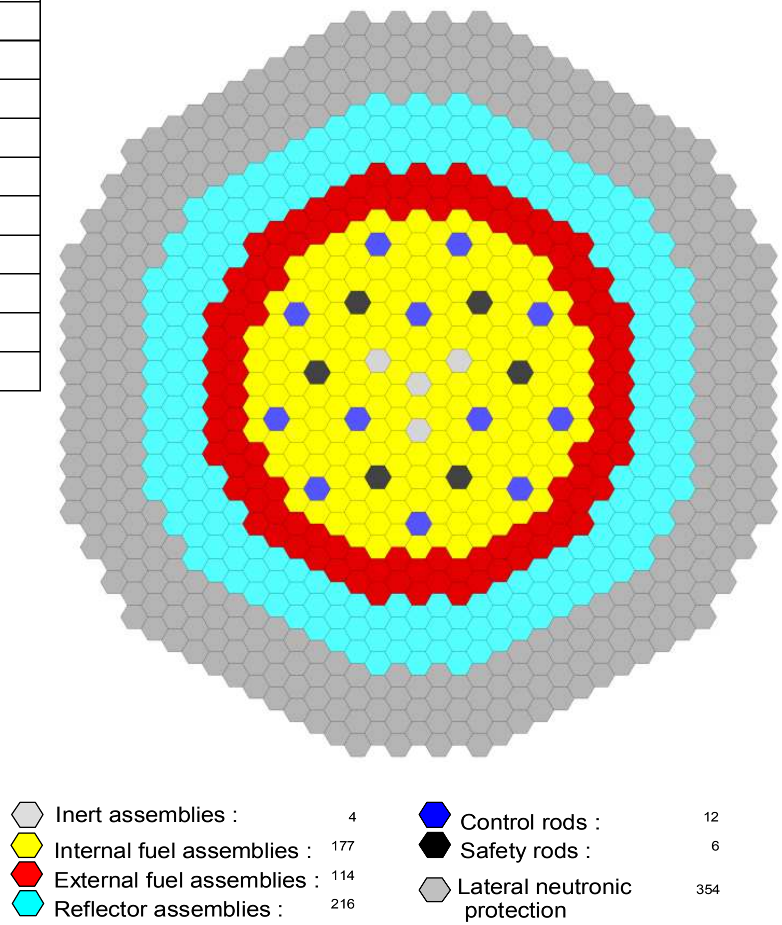
- Experimental irradiations (in support to the SFR development)

Core design option

1500 MWth CFV V1 Core	
Fuel sub assemblies	291(177+114)
Control rods	18 (12+6)
Fuel	$(UPu)O_2$
Clad material	Austenitic clad (AIM1)
Number of batches / Fuel cycle length (efpd)	4 x 360
Fuel residence time (efpd)	1440
$\Delta\rho$ core burn-up reactivity loss (pcm/efpd)	-4,3
Na void worth ($)	-0,5
Breeding gain	-0,02
Plin max BOL (W/cm)	483

(Patent CEA EDF AREVA)



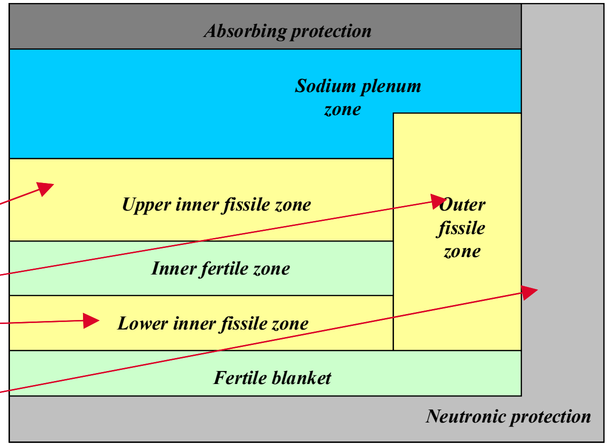


CFV Core (Coeur Faible Vidange)
Sodium void worth strongly reduced
➔ Na void effect < 0

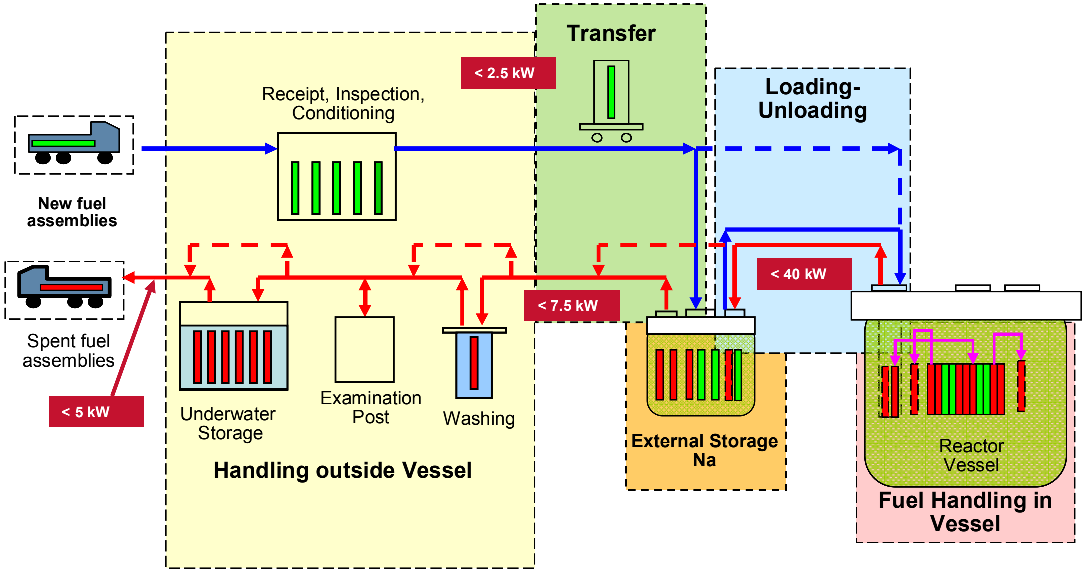
Transmutation potential in ASTRID

Assumptions

- CFV V1 Core
- Cycle of 360 EFPD
- Priority to Americium (241Am: 81%, 243Am: 19%)
- Homogeneous mode : 4 cycles
- Heterogeneous mode : 5 cycles for MABB



- Fuel handling

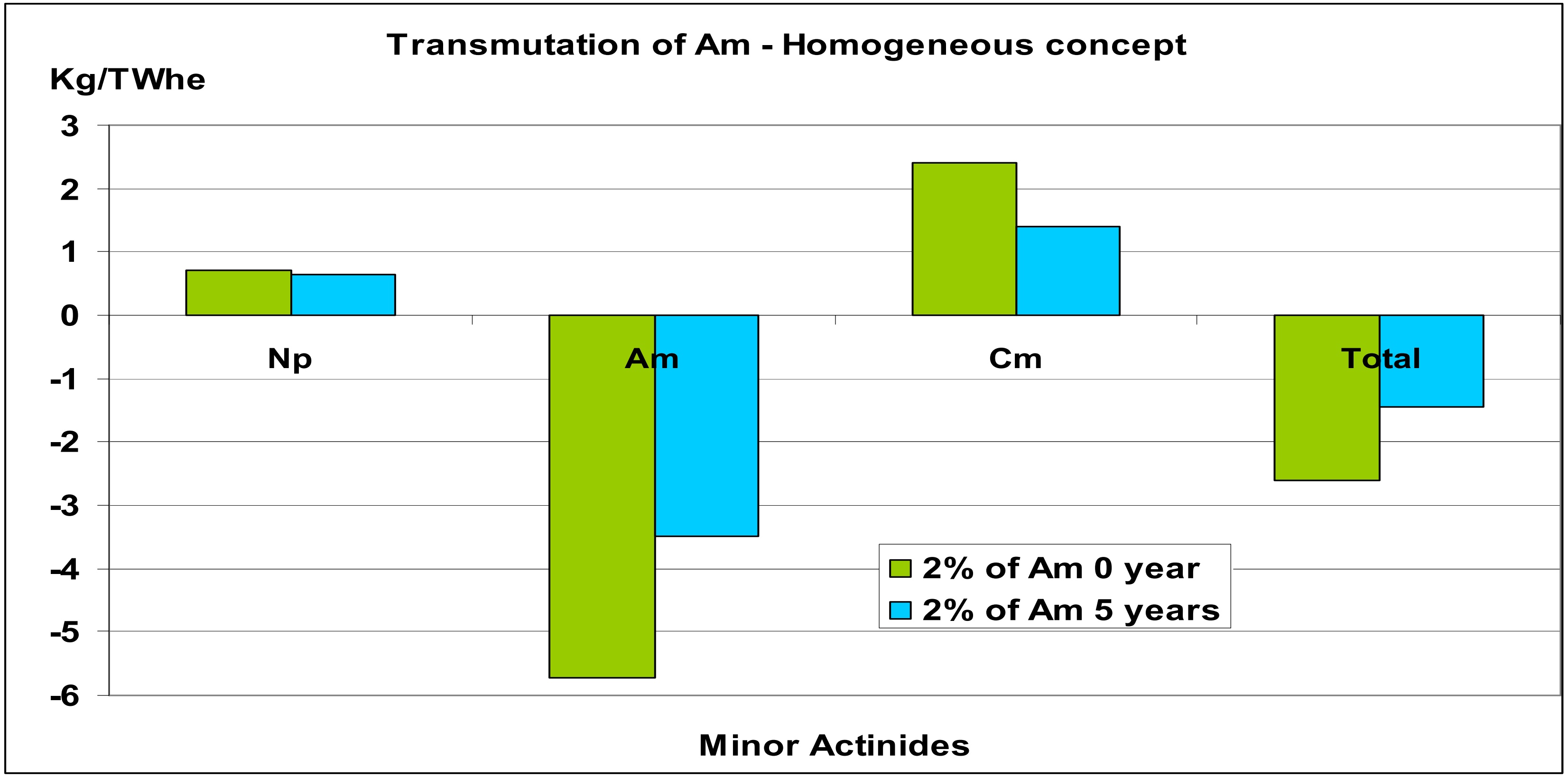


Schematic presentation of the chain of fuel handling

Transmutation of Am in ASTRID

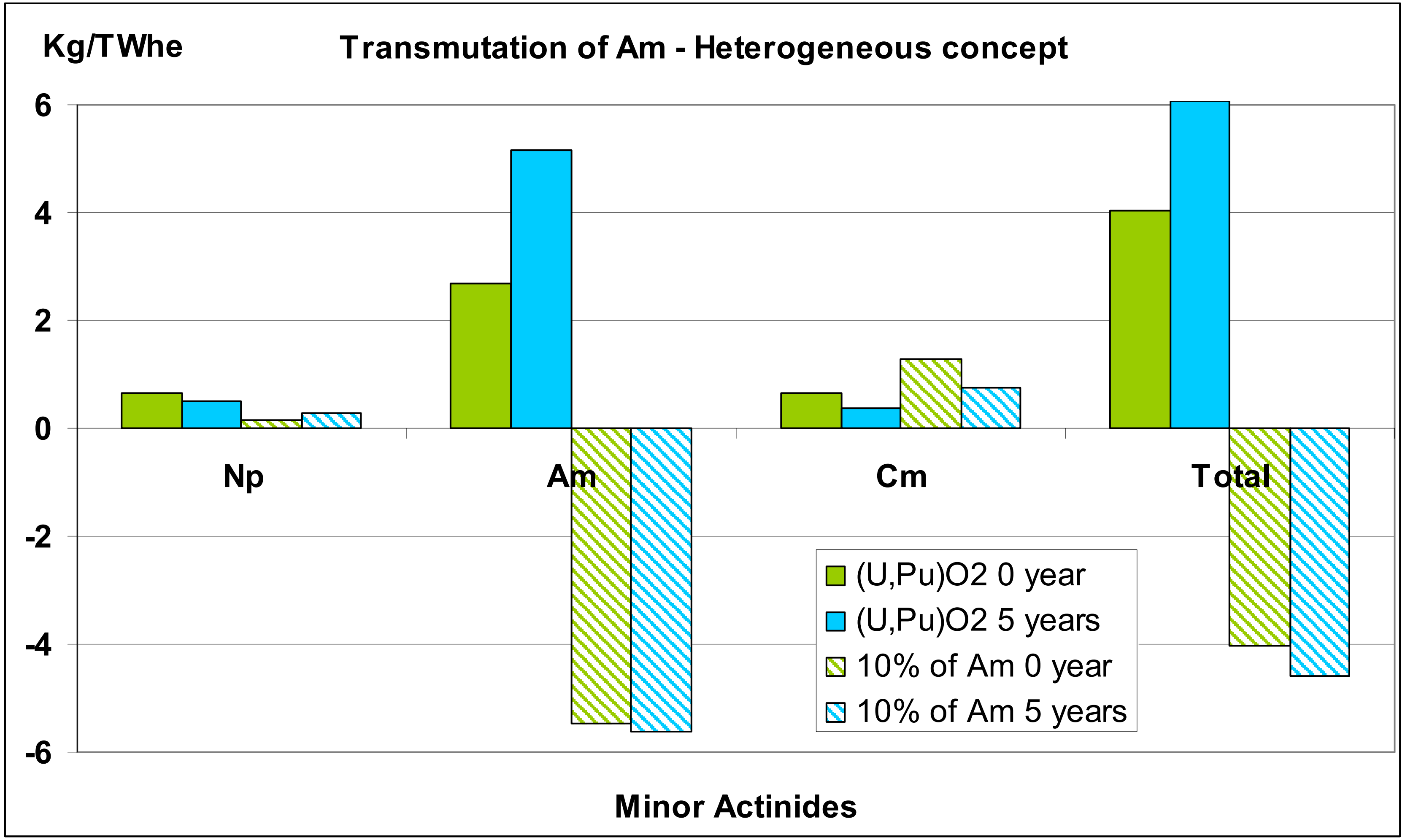
The main objective is to burn the americium produced by the standard $(U,Pu)O_2$ fuel in ASTRID ➔ Initial Am limits

- **Homogeneous mode ~ 2% of Am**



Transmutation of Am in ASTRID

Heterogeneous mode ~ 10 % of Am



Transmutation of Am in ASTRID

- **Homogeneous concept with 2% of Am**
  - **Negative balance for Am**
  - **Increase de Cm production (x3 after 5 years of cooling time)**
  - **Negative balance for total minor actinides**
- **Heterogeneous concept with 10% of Am**
  - **Am consumption > Am production in the MOX after 5 years of cooling time**
  - **Consumption of total MA ~ Production in the MOX** (3 years of cooling)

➔ **Impacts on :**

- **Core safety**
- **Fuel handling**

Transmutation of Am in ASTRID : Impacts on core safety

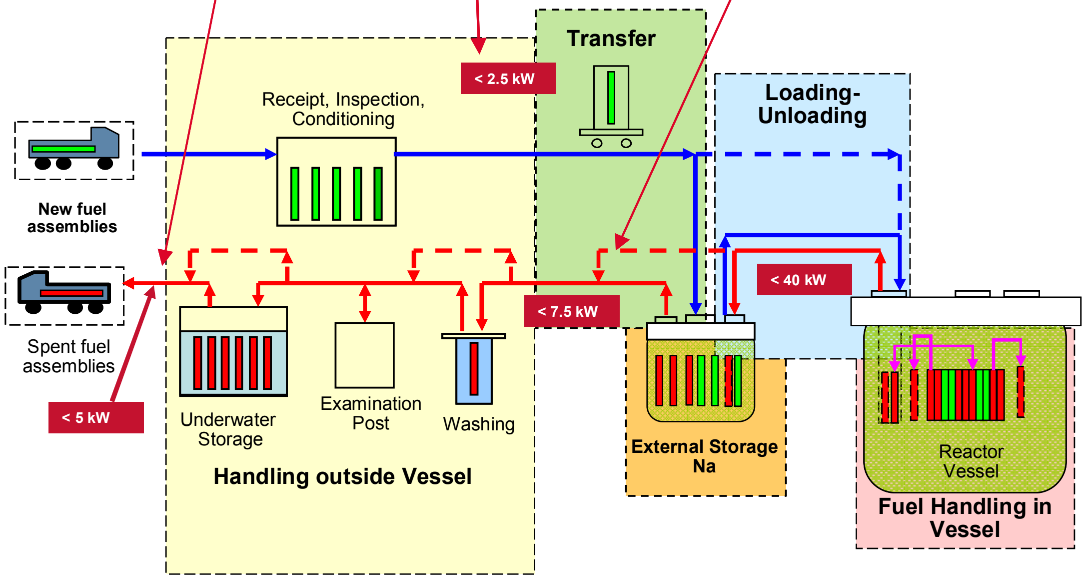
core safety coefficients		(U, Pu)O2	Homogeneous 2%	Heterogeneous 10%
Void coefficient (EC)	$	-1.05	-0.54	-1.05
Margin to melting	°C	>300	>300	>300
Max. temperature of Na	°C	908	909	904
Temperature neutron choking	°C	737	729	725
$\delta\rho$ max insert	pcm	243	221	228

The results for the two modes of transmutation show that the core safety coefficients are not impacted, including a sodium void coefficient that remains negative

Transmutation of Am in ASTRID : Impacts on fuel handling

Handling fuels	(U, Pu)O2	Homogeneous 2%	Heterogeneous 10%
New sub-assembly, aging time 2 years			
Power (kW/sub-assembly)	**0.39**	**0.55**	**0.95**
Spent fuels			
Time to reach 40 kW	**< 1 day**	**1 day**	**< 1 day**
Time to reach 7.5 kW (days)	**68**	**168**	**350**
Time to reach 5 kW (days)	**123**	**291**	**485**

The results for the two modes of transmutation show that new and spent fuel sub-assembly handling systems are not impacted.



Transmutation in ASTRID : Np and Cm

- ❑ Americium is a priority
- ❑ The substitution of part of the americium by neptunium has no effect on the impact on the various analysis criteria
- ❑ Curium is not taken into consideration for the transmutation demonstration in ASTRID

  ➔Significant impact on handling of new sub assembly

  (decay heat and neutron source)

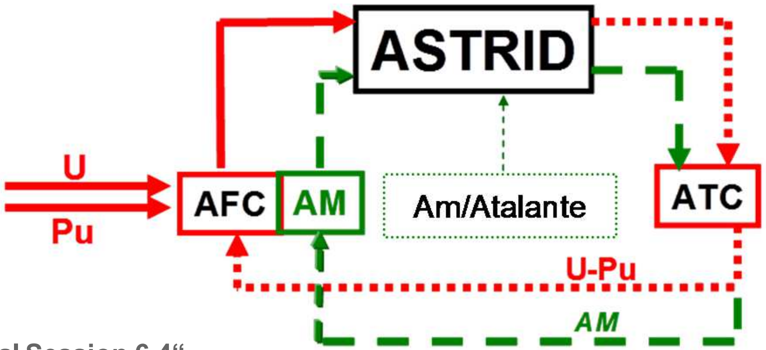
Summary and future prospects for incorporating Am in ASTRID

- Potential to demonstrate the minor actinide transmutation on an industrial scale in the CFV V1 core of ASTRID :
  - Homogeneous concept : 2% of Am in a standard fuel
  - Heterogeneous concept : 10% on UO_2 in the radial blanket

- The objective of ensuring a balance in the Am (and total minor actinides) flow in the ASTRID fuel cycle may be obtained without any impact on the design of the core and handling systems for the management of the new and spent fuel sub-assemblies

- Several experimental phases in ASTRID to implement different transmutation scenarios using homogeneous and heterogeneous concepts.

➔ the availability of facilities involved in the ASTRID material cycles



Thank you for your attention

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