ACTINIDE MANAGEMENT WORKSHOP

Impact of main reactor physics parameters on actinide recycling performances

A.Zaetta

CEA / Nuclear Energy Directorate

Cadarache

Objectives and context

- Actinide management covers a very large scope of reactors and fuel cycles options, as the content of this workshop illustrates.

- Performances comparison of different strategies needs detailed scenarios studies, taking into account technical constraints and performance limits both for reactors and fuel cycle

- Equilibrium situations (in terms of mass balance and isotopic stabilization) allow to characterize each strategy

Objectives and context

- Transitoire phases to go from one strategy to an other one are also very important ➔ time aspect (reality is not pure équilibrium situation.....)

- Large disparities exists between national, regional and worldwide situations

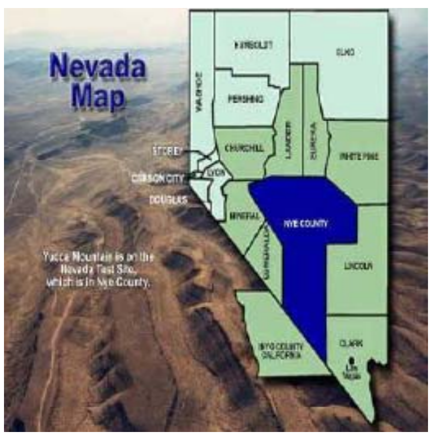
- Nevertheless, is it possible, in a simplified manner, to identify key parameters and compare the potentials of the various actinide management options, as regards the general question of actinide recycle performances ?

Mines : 20 t U nat

Enrichment 15000 UTS

Fabrication
2,2 t U enr

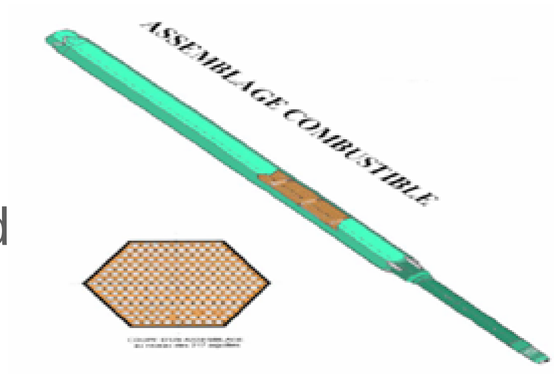
Reactor : LWR



DISPOSAL
Pu = 29 kg
M.A = 3,5 kg

Equilibrium situations : CLOSED CYCLE Pu (FR for 1 TWhe)

U depleted



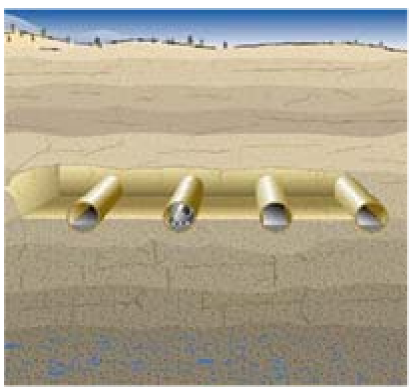
Fabrication 0,8 t MOX

Reactor : FR

U,Pu

Reprocessing
SF 0,8 t

FP, MA



DISPOSAL
Pu = 0,1 kg
M.A = 4,2 kg

Equilibrium situations : Comparison

	Open Cycle 100%UOX	Pu once cycling 90% UOX 10% MOX	Pu Recycling PWR [MOX_EU , HCR]	Pu recycling FR 100% MOX	Pu + MA recycling FR 100% MOX
Natural U and UTS	1	0,9	[0,85 , 0,50]	0	0
Reprocessing	0	2,5	2,5	1	1
WASTES Pu	1	0,6	<1%	<1%	<1%
M.A	1	1,3	[2 , 3,5]	1,2	<1%
Decay heat (200 y)	1	0,85	0,70	0,60	0,03
Pu Inventory Reactor + Cycle	1	5	[15 , 30]	30	30

Actinide recycling: reducing U nat, increasing reprocessing needs
reducing mass, volume and thermal power of wastes
➔ increase deep storage capacity and acceptance ?
Pu availability is crucial ➔ transient situations

Impact on deep repositoty (SCK•CEN calculation for a repository in clay)

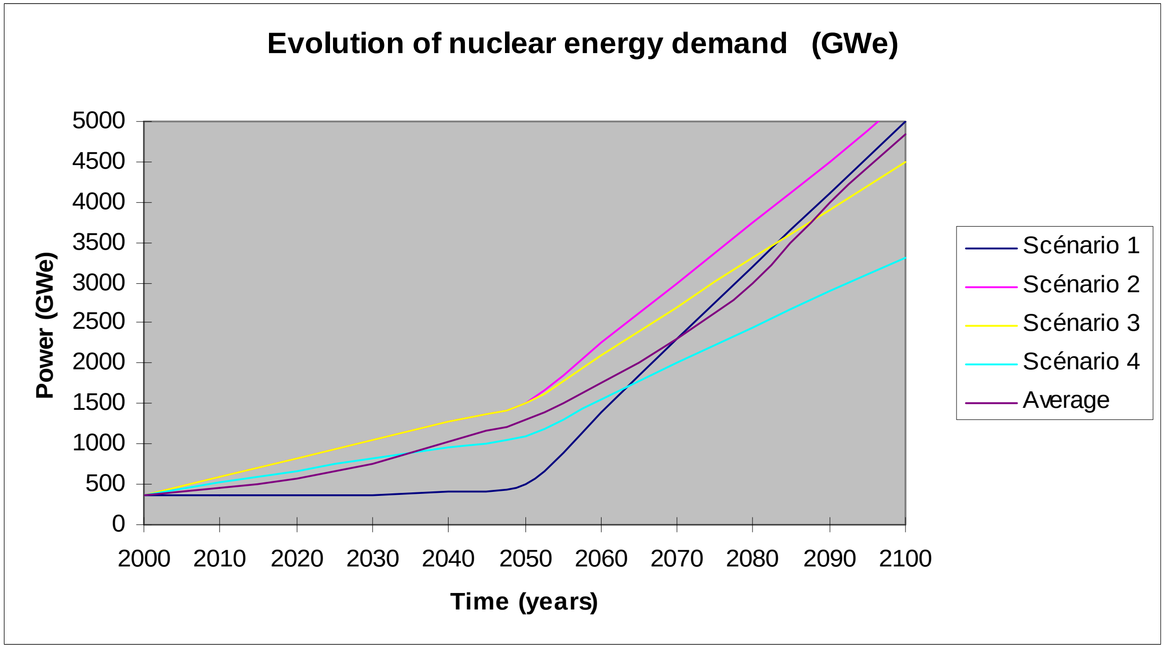
	Unit	1a	1b	2a	3cV1	
SF assemblies	#/TWhe	3.981	0.437	–	–	
HLW canisters	#/TWhe	–	2.592	3.987	1.181	
NM canisters	#/TWhe	–	–	–	0.085	
Cs-waste canisters	#/TWhe					
Thermal output HLW (50 a)	W/TWhe	2 110	2 031	1 997	571	
Length disposal galleries	m/TWhe	7.033	6.77	6.657	2.016	
Relative length disposal galleries	–	1	0.963	0.947	0.287	

Single or multiple recycling of Pu does not significantly reduce the thermal output of the high level waste. On the other hand a fully closed cycle such as fuel cycle scenario 3cV1 leads to a reduction of the decay heat and the required length of disposal galleries by a **factor 3.5**. If longer cooling times are considered (200 years) reduction of decay heat reach a **factor 30.**

Transient situations : World level energy demand

IIASA propose 4 type of scenarios :

- 2 based on high worldwide growth (coal + nuclear)
- 1 more limited needs
- 1 voluntary energy saving



Average scenario: installed nuclear power would double between today and 2030 to reach 0,75 TWe and about 5 TWe in 2100.

Transient situations : World level energy demand

How answer to this demand ?
Deployment of GEN 3 LWR with UOX fuel will enable to reach objective but using all conventional natural U resource (15 Mt) and quite a large part of unconventional one (15 Mt) .

CATEGORY of Uranium resources (million tons = Mt)					
	Conventional				
	Identified (deposits)		Undiscovered		
Cost of recovery $/kgU	Reasonably Assured Resources ❶	Inferred Resources ❶	Prognosticated Resources ❷	Speculative Resources ❸	❶ Based on direct geological evidence ❷ Based on indirect geological evidence ❸ Extrapolated values
< 40	1.95	0.80	1.7	4.6	
40 to 80	0.70	0.36			
80 to 130	0.65	0.29	0.82		
> 130	-	-	?	2.9	Unconventional
Subtotal	3.30	1.45	2.52	7.5	
General total	4.75		10.0		15 to 25

General total of conventional resources: 14,750 000 t
World demand in 2006: less than 70,000 t
Resources: > 200 times 2006 demand

+ With Gen IV Fast Breeder Reactor, resources are virtually unlimited

Table 1 - Estimate of Uranium resources as of 2005

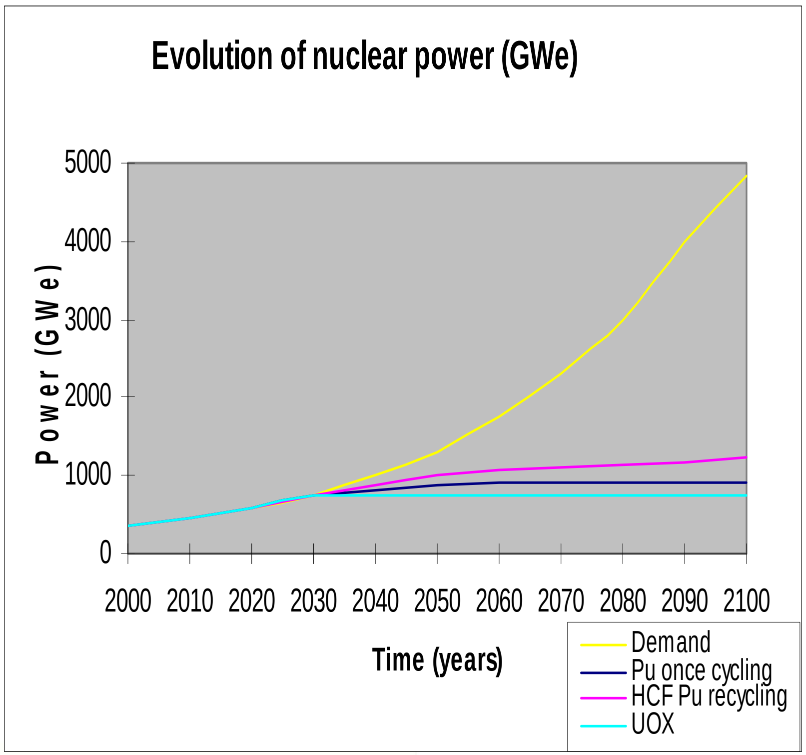
CAPUS, ICAPP 2007

Tension on market ?, Cost impacts ? , ...

Transient situations : actinide recycling potential

How actinide recycling options can contribute to this challenge ?
The key point is Pu production and his availability.

Hypothesis : A stable LWR UOX fleet of 0,75 TW is producing Pu during all the période [2030, 2100]
All Pu produced during the century is available (quite optimistic !)



Pu feeds :

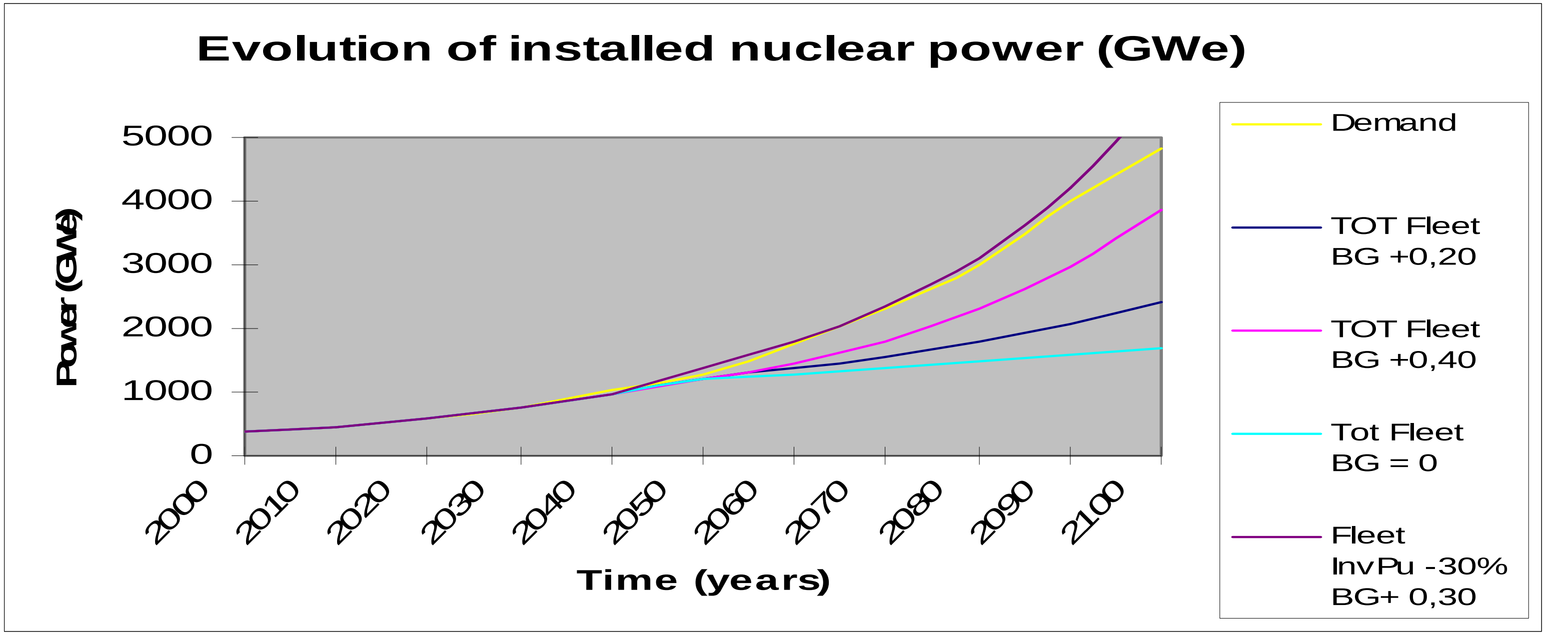
1) Standard LWR once cycling
2) High Conversion Ratio LWR (HCR = 0,94) with Pu recycling

GAIN on Installed power :

Pu once cycling = + 20%
Pu recycling in HCR = +60%
(impact of high Pu inventory 10 t/GWe)

Transient situations : actinide recycling potential with FR

Same approach with Fast Reactors

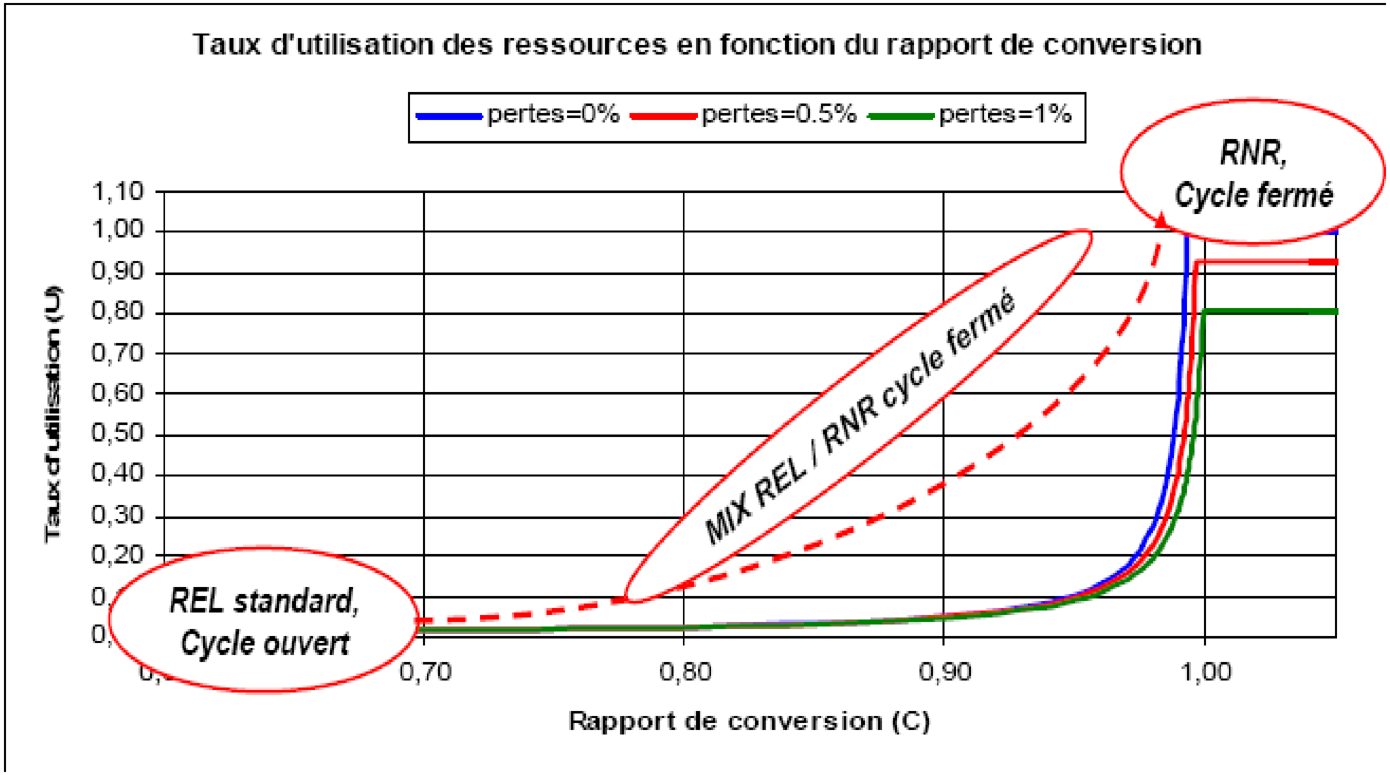


With BG = 0 ➔GAIN = factor 2 (half Pu stock, half Pu production)
With BG [0,20, 0,40] ➔GAIN = factor [3, 5]
Combine low Pu Inventory + BG = 0,30 ➔GAIN = factor 7
M.A recycling can reduce by a factor 2 total inventory on the period

Key roles = Breeding Gain , Pu core inventory and scenario duration

Don't forget : LWR 60 Pu production = FR's Pu inventory

Uranium utilization and breeding



• Closed cycle allow a gain of 2 order of magnitude on U utilisation compared to open cycle
•Mixte LWR / FR could be a transition and an optimisation for waste management
•LWR can be improved ➔ High FC cores ➔CR # 1

CONCLUSIONS ON ACTINIDES RECYCLING POTENTIALS

- Pu once cycling in LWR :

  Gain is 10 % to 20 % on Unat consumption

  Reduction HL wastes volume

  Gain on storage volume (facteur 7)

  MOX SF = Pu stock for FR deployment

  ➔ Well adapted to nucleaire renaissance with management of spent fuel associated

- Pu recycling in LWR

  Gain is 50% to 100 % on Unat or power installed

  HCR LWR potential limited by high Pu reactor inventory

  With CR # 1 , Keep Pu constant for FR deployment

CONCLUSIONS ON ACTINIDES RECYCLING POTENTIALS

- Pu recycling in FR :

  High potential : Installed power may be increased by factor 2 to 10 depending of BG.

  U utilization = factor 100

  Pu availability is crucial ➔ preserve it (waste management ?) and extract it from SF (Reprocessing capabilities ?)

- Minor actinides recycling :

  Inventory reduction by a factor 2

  Wastes : mass reduction by a factor 150

  potential to increase capacity of disposal