THE NUCLEAR FUEL CYCLE : STATUS,PROSPECTS and CHALLENGES

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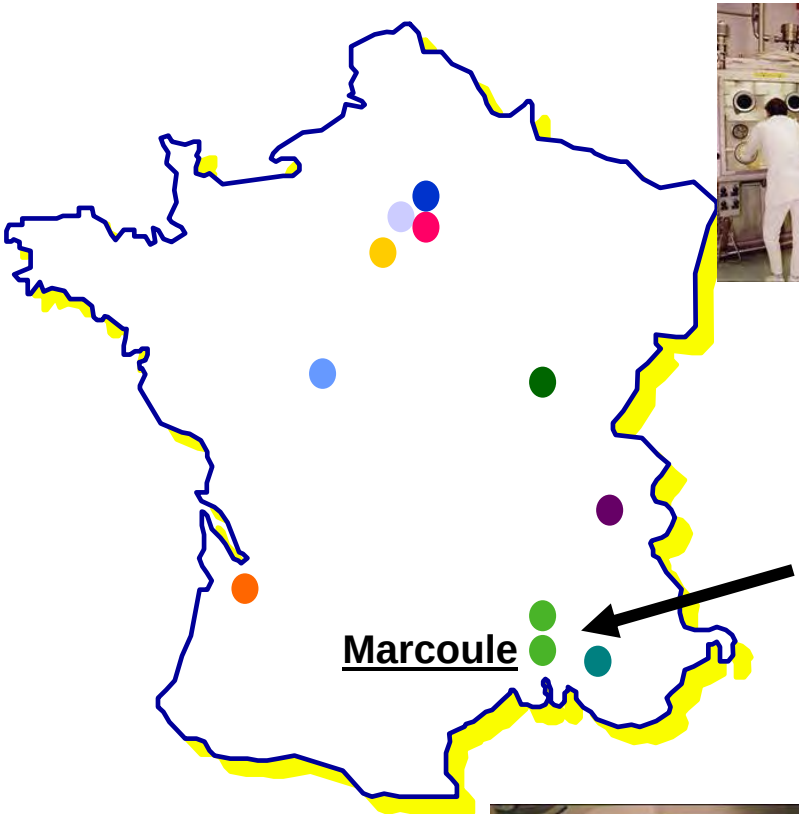
CEA *AT A GLANCE*

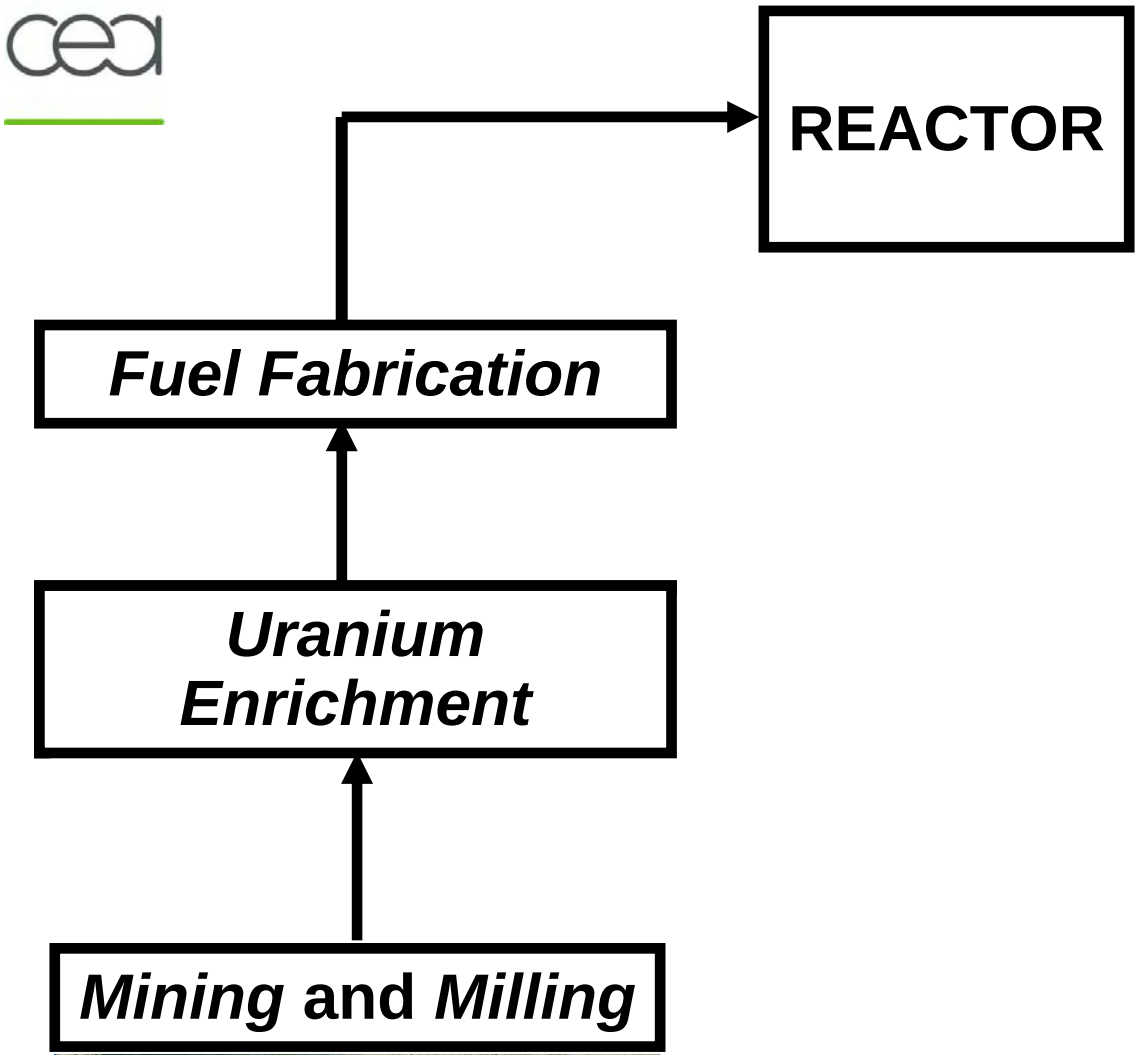
THE *ATALANTE* FACILITY AT CEA, MARCOULE



THE NUCLEAR FUEL CYCLE : STATUS,PROSPECTS and CHALLENGES

1- the nuclear fuel cycle
2- how to manage spent fuel?
3- advanced recycling options for the future
4- some challenges for chemists…

THE NUCLEAR FUEL CYCLE



THE NUCLEAR FUEL CYCLE

REACTOR

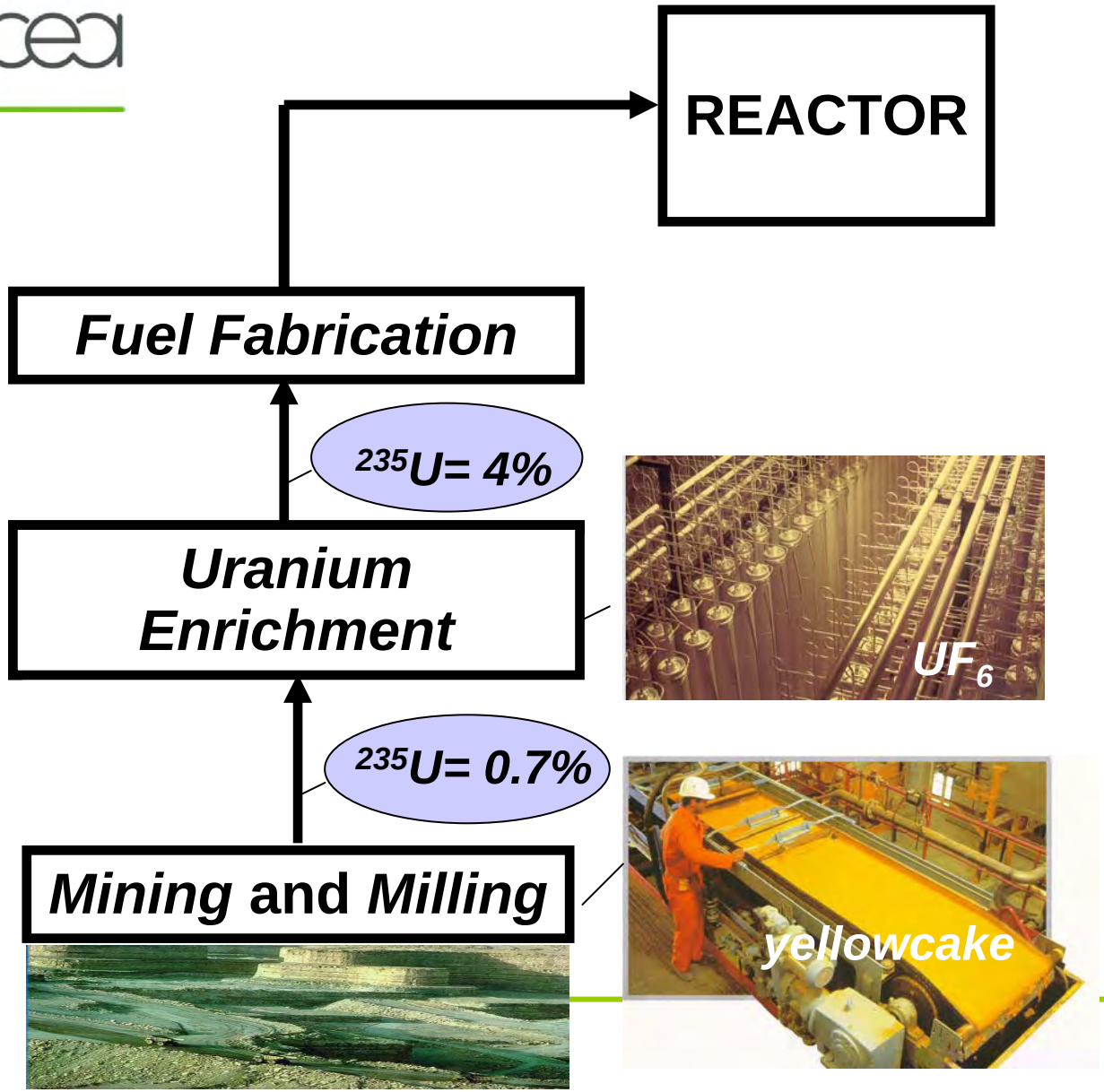
Fuel Fabrication

Uranium Enrichment

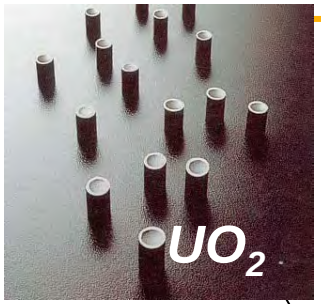
^{235}U= 0.7%

Mining and *Milling*

THE NUCLEAR FUEL CYCLE



THE NUCLEAR FUEL CYCLE



REACTOR

Fuel Fabrication

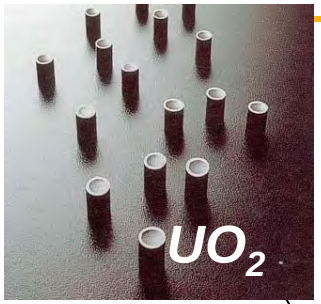
$^{235}U = 4\%$

Uranium Enrichment

$^{235}U = 0.7\%$

Mining* and *Milling

THE NUCLEAR FUEL CYCLE



REACTOR

Spent Fuel

Fuel Fabrication

^{235}U= 4%

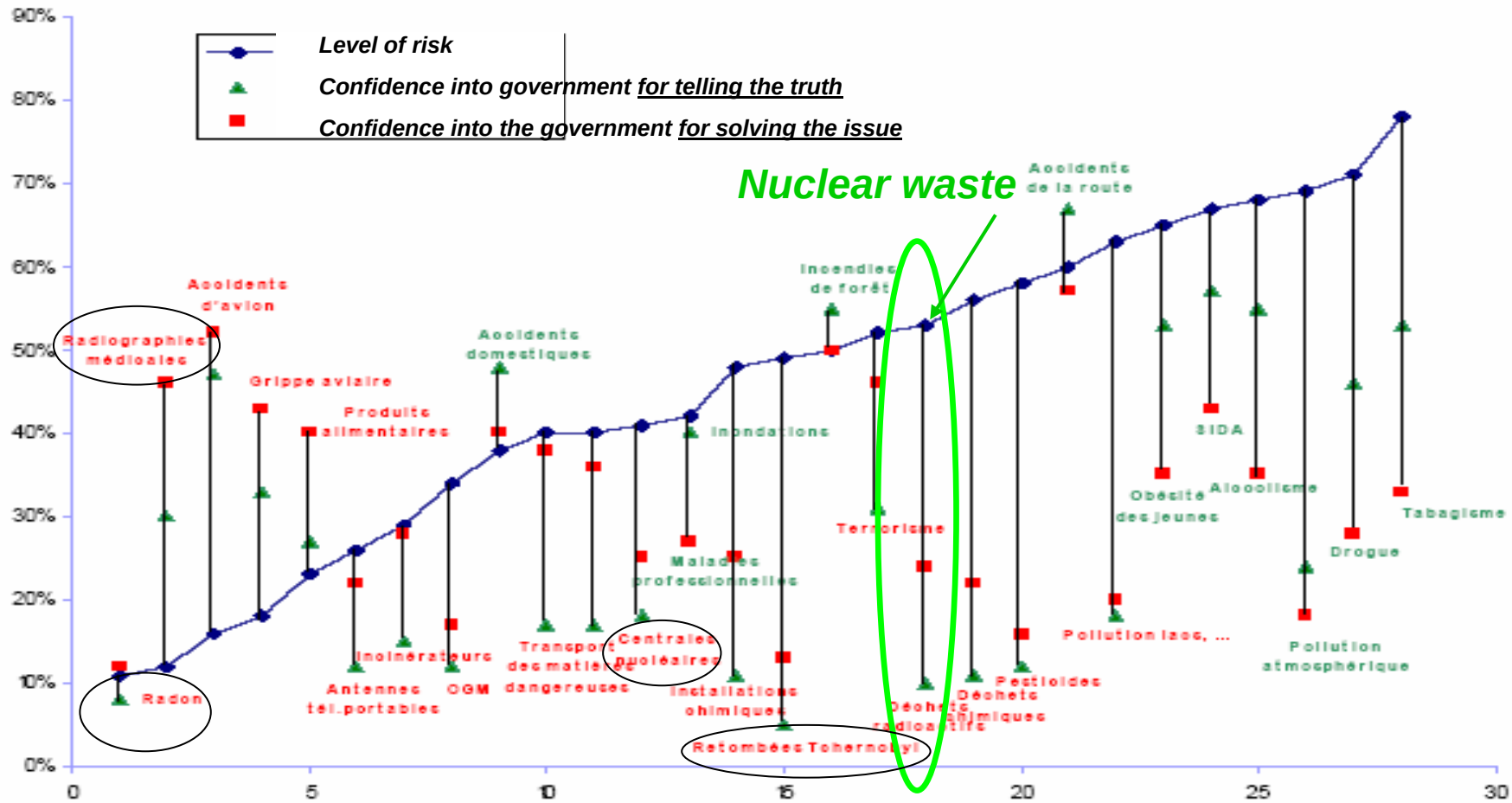
Uranium Enrichment

^{235}U= 0.7%

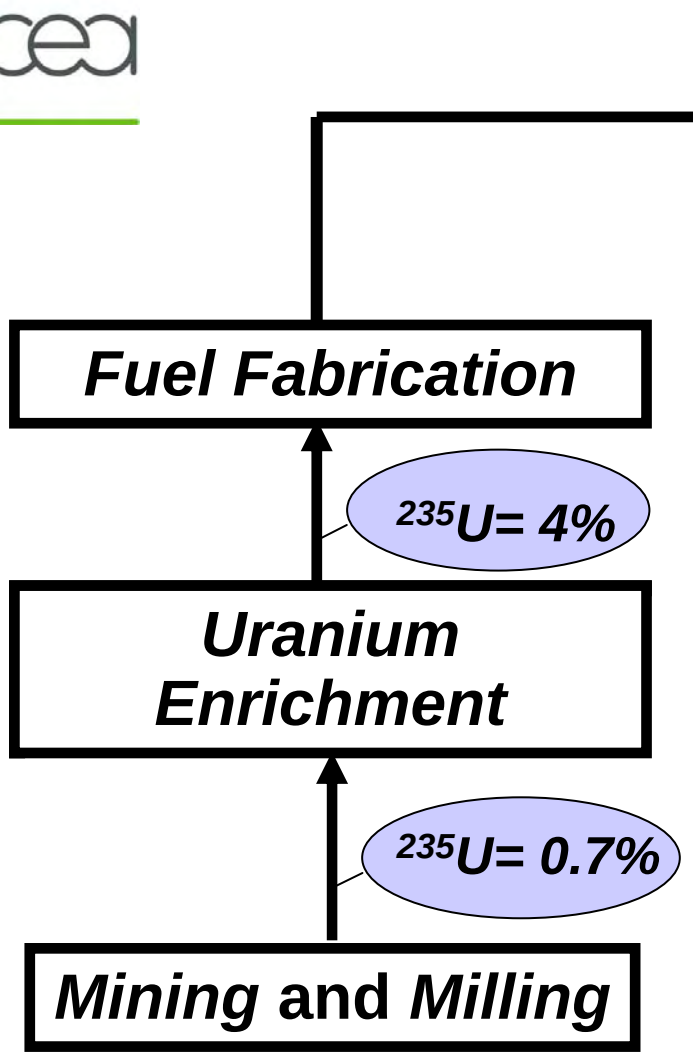
Mining* and *Milling

ABOUT RISKS…

Source: "IRSN barometer" 2006



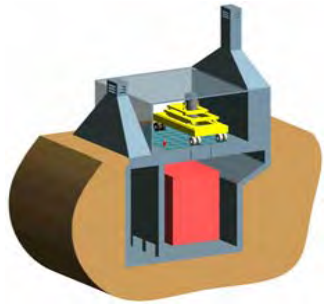
THE NUCLEAR FUEL CYCLE



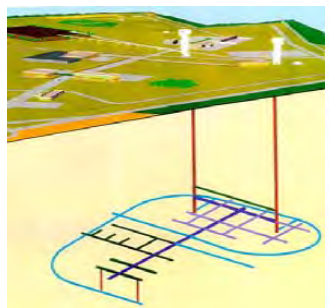
a dangerous waste,
& an asset

SPENT FUEL MANAGEMENT: WHAT *OPTIONS* ?

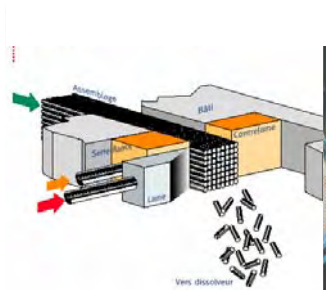
- ***INTERIM STORAGE***



- ***DIRECT DISPOSAL***



- ***PROCESS & RECYCLE***



FUTURE NUCLEAR SYSTEMS: *REQUIREMENTS*

(1) SAFETY

(2) ECONOMICS

(3) « SUSTAINABILITY » :

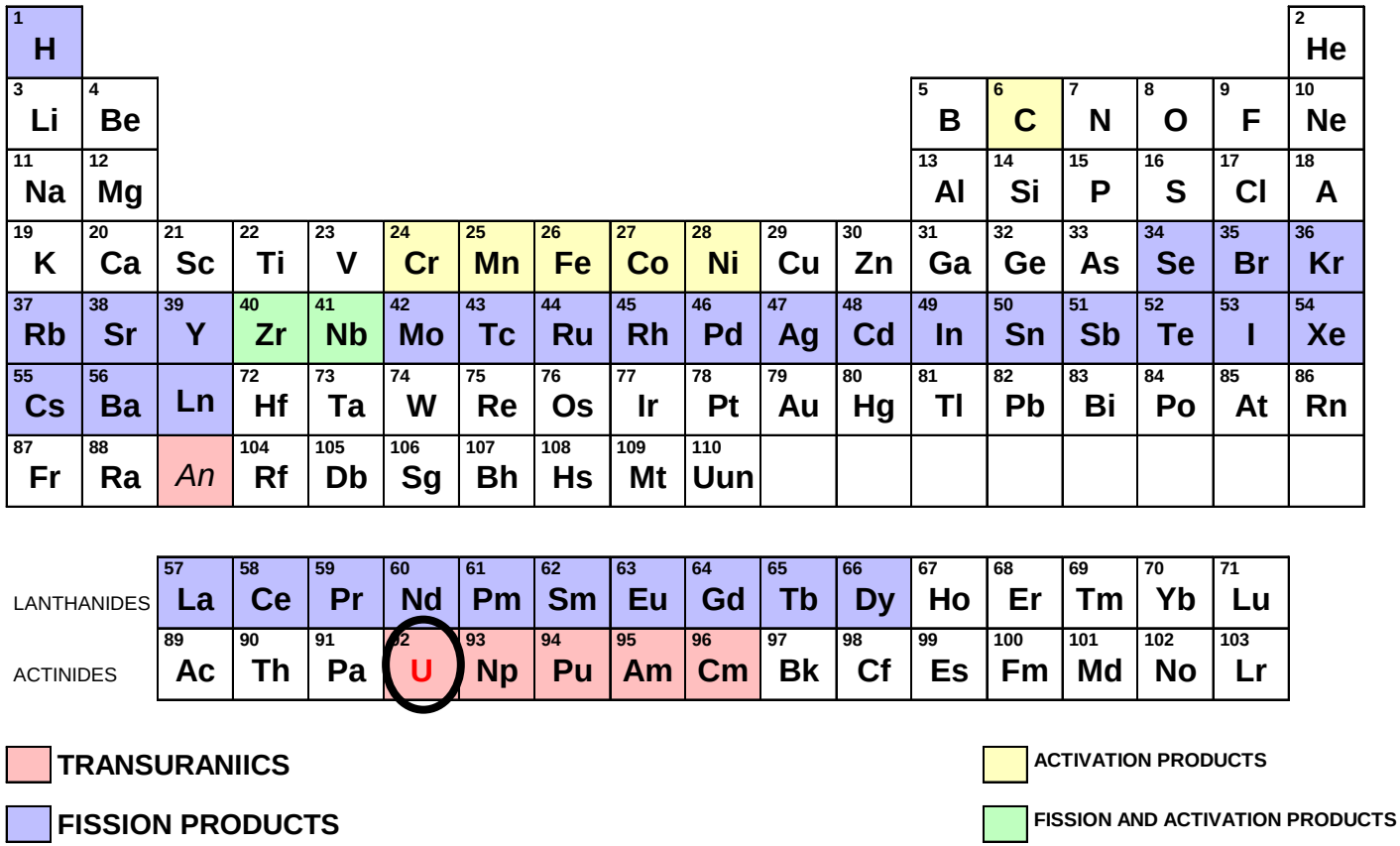
. rational use of natural resources

. waste minimization

. resistance vs. proliferation risks

long-lasting options= recycling options

THE SPENT NUCLEAR FUEL



THE SPENT NUCLEAR FUEL

Uranium (95%)

Fission Products (4%)

Plutonium (1%)

Minor Actinides (0.1%)

Average Content

THE SPENT NUCLEAR FUEL

235U=0.9%

Uranium (95%)

Fission Products (4%)

Plutonium (1%)

Minor Actinides (0.1%)

Average Content

THE SPENT NUCLEAR FUEL

235U=0.9%

Uranium (95%)

Fission Products (4%)

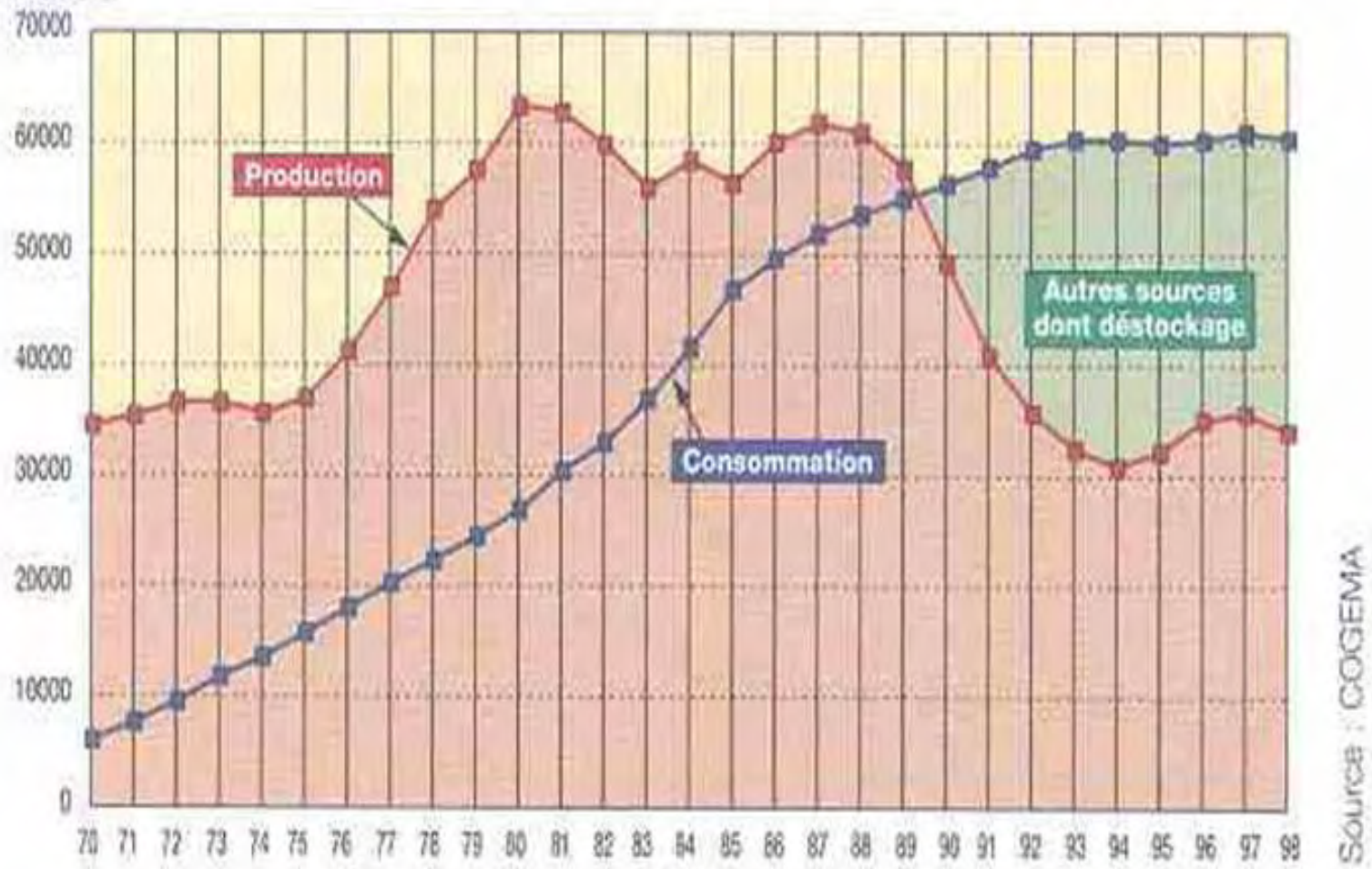
Plutonium (1%)

Minor Actinides (0.1%)

Average Content

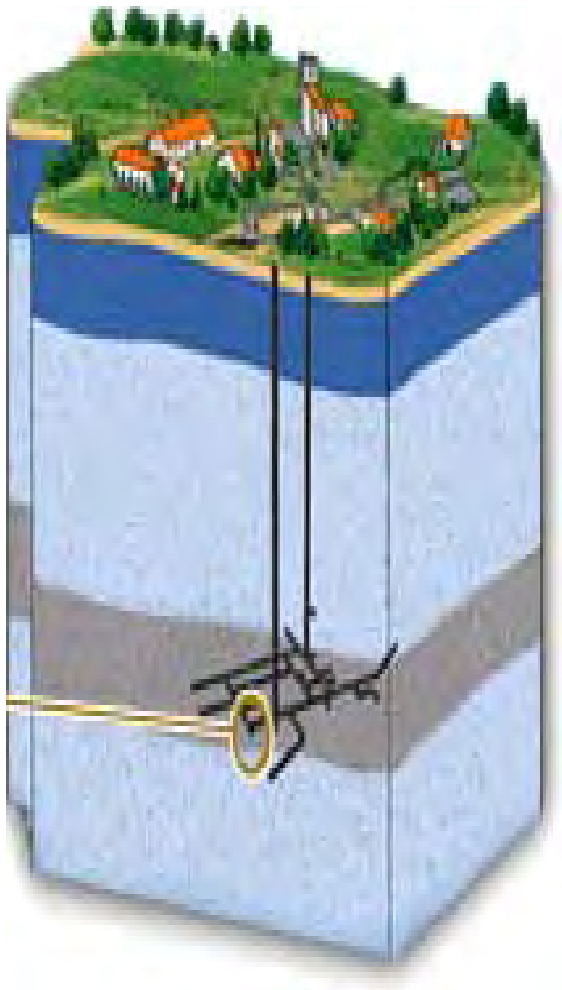
Fissile isotops = 75%

URANIUM PRODUCTION AND CONSUMPTION



2005 records : 41 600 tons produced
67 500 tons needed

MINIMIZING *WASTE*



-VOLUME

-HEAT EMISSION

-TOXICITY ...

SPENT FUEL AMOUNT and long term TOXICITY

Uranium

Fission Products

Plutonium *(1%)*

Minor Actinides *(0.1%)*

Average amount

Plutonium

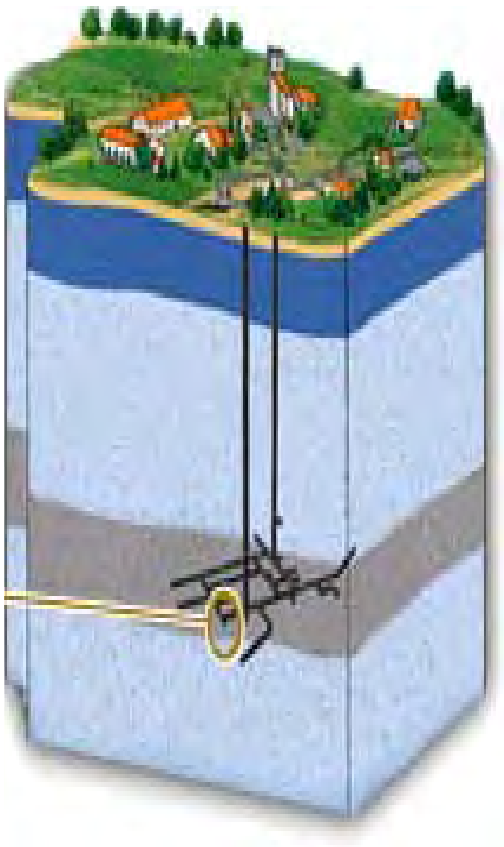
Minor Actinides

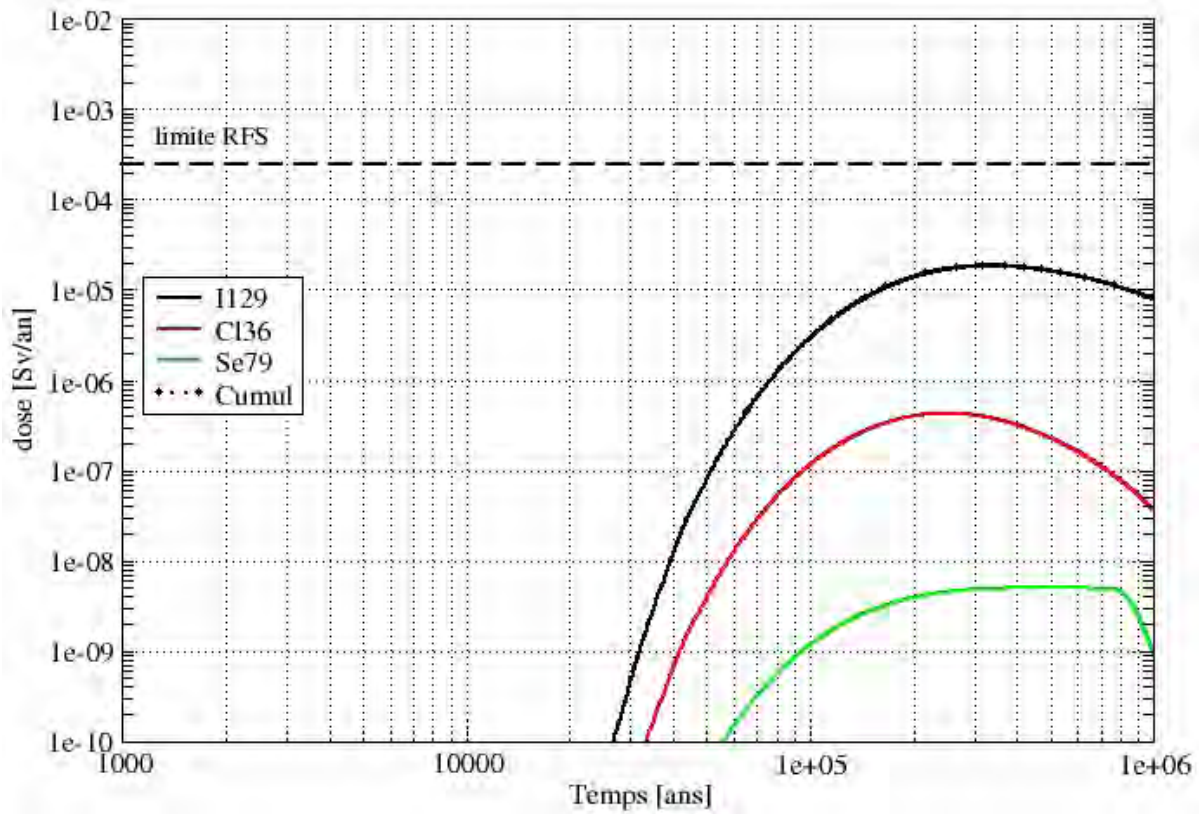
Fission Products

Uranium

Radiotoxicity > 1 000 ans

DEEP REPOSITORY (ANDRA, « CLAY REPORT », 2005)

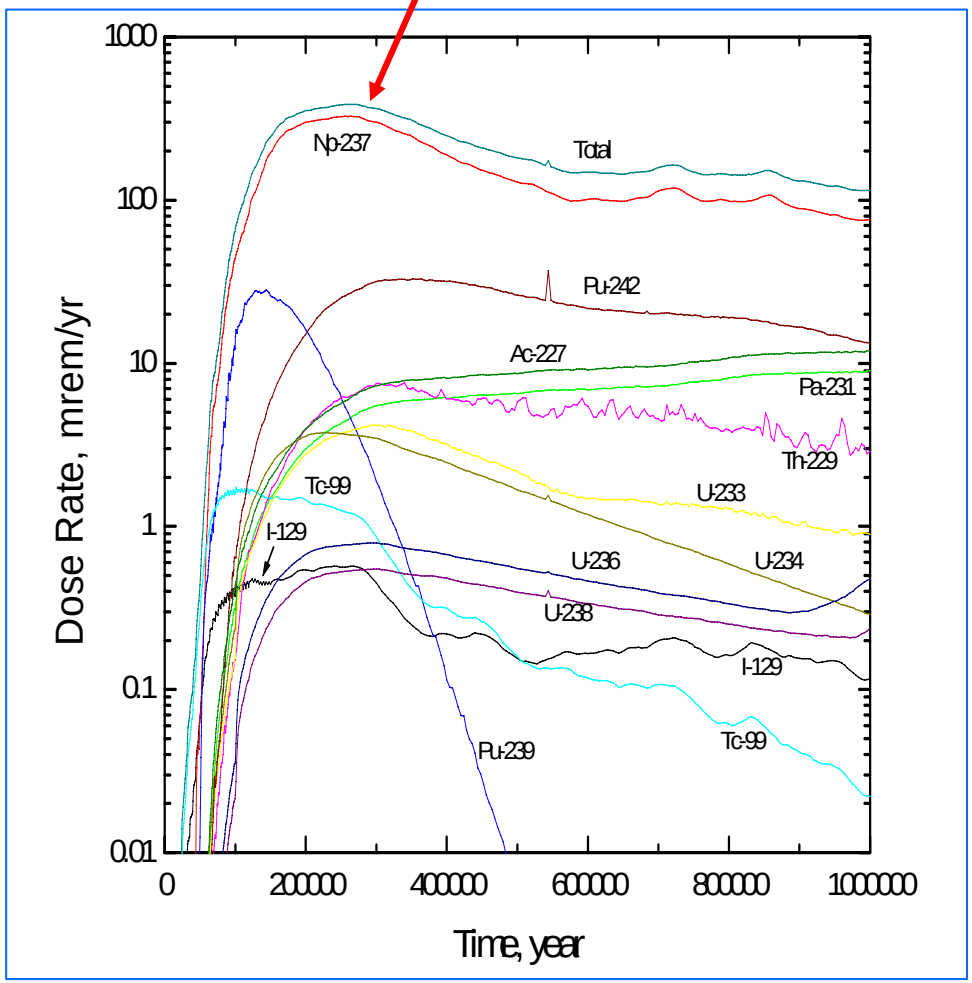




ACTINIDE DON'T MIGRATE…

ABOUT ACTINIDE MIGRATION…

YUCCA MOUNTAIN, Nevada



SPENT FUEL REPROCESSING AND RECYCLING

(UOX)

(MOX)

REACTORS

Spent fuel

Fuel Manufacturing

Reprocessing

Plutonium

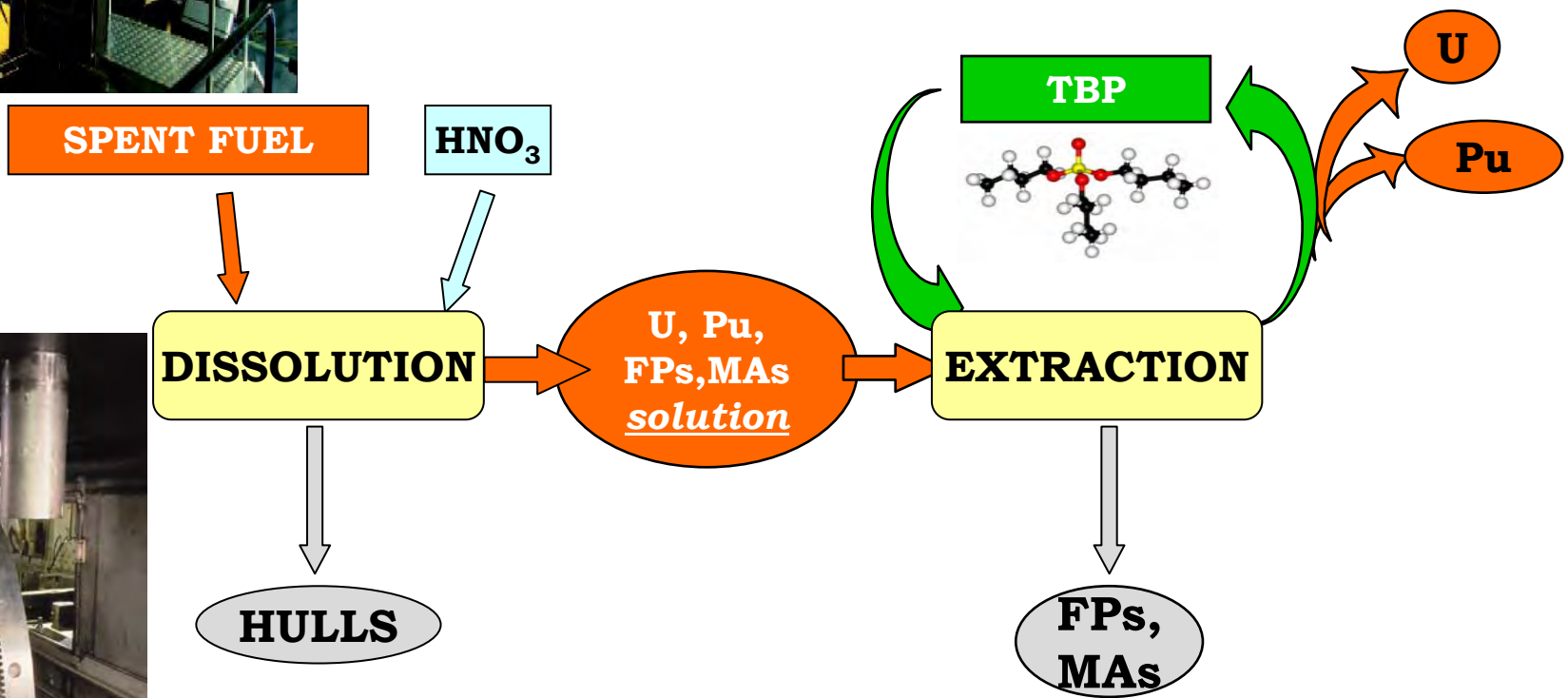
WASTE (FPs & MAs)

Uranium Enrichment

Uranium

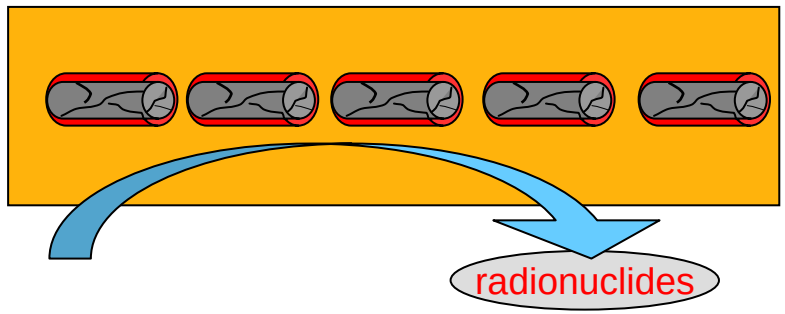
Uranium Mining & Milling

THE PUREX PROCESS

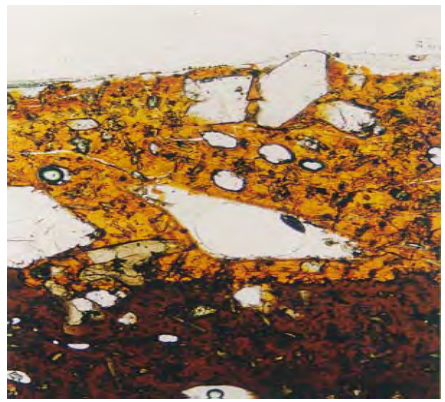


FISSION PRODUCTS VITRIFICATION

GLASS : *ALTERATION KINETICS*



Altération

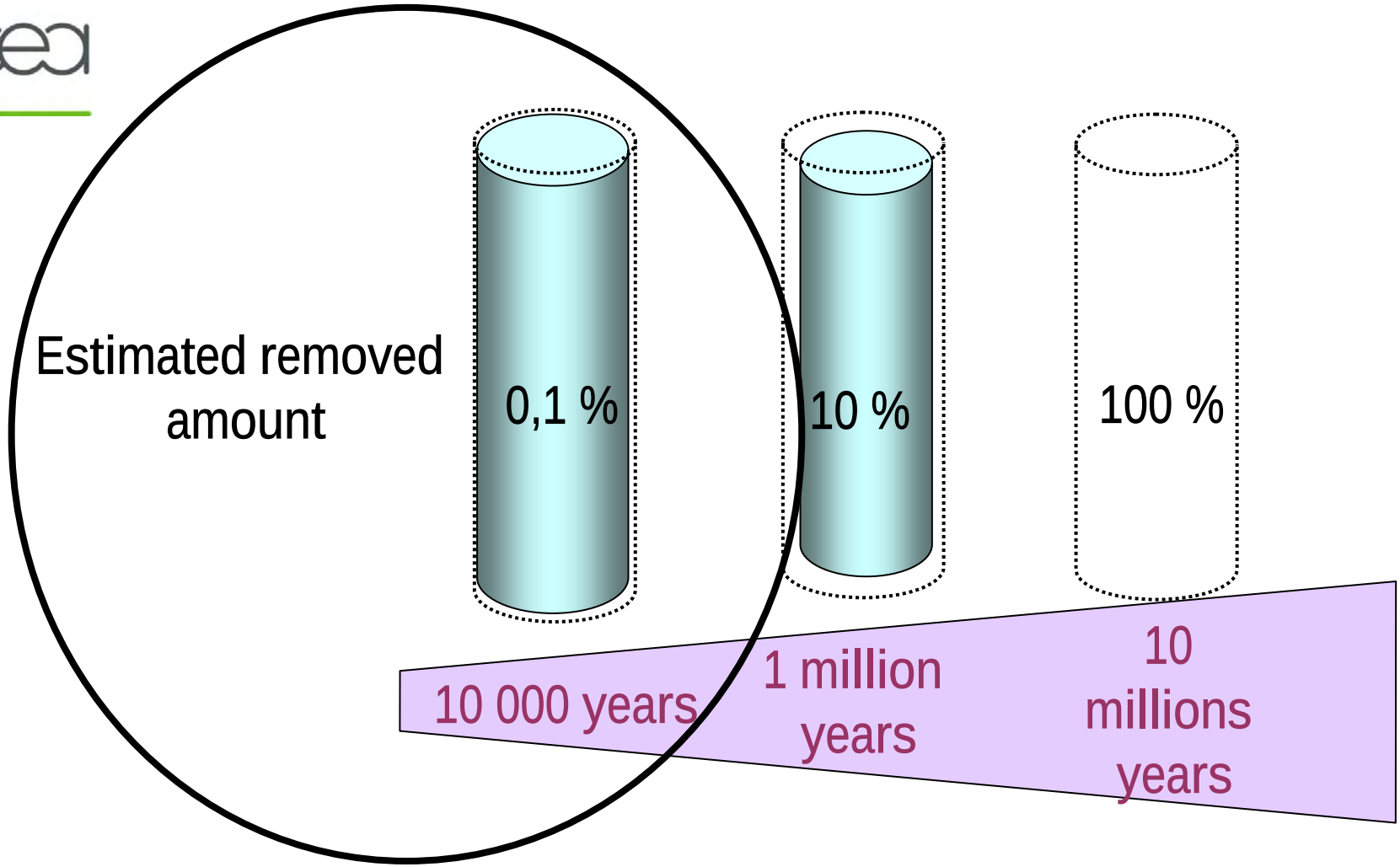


Time

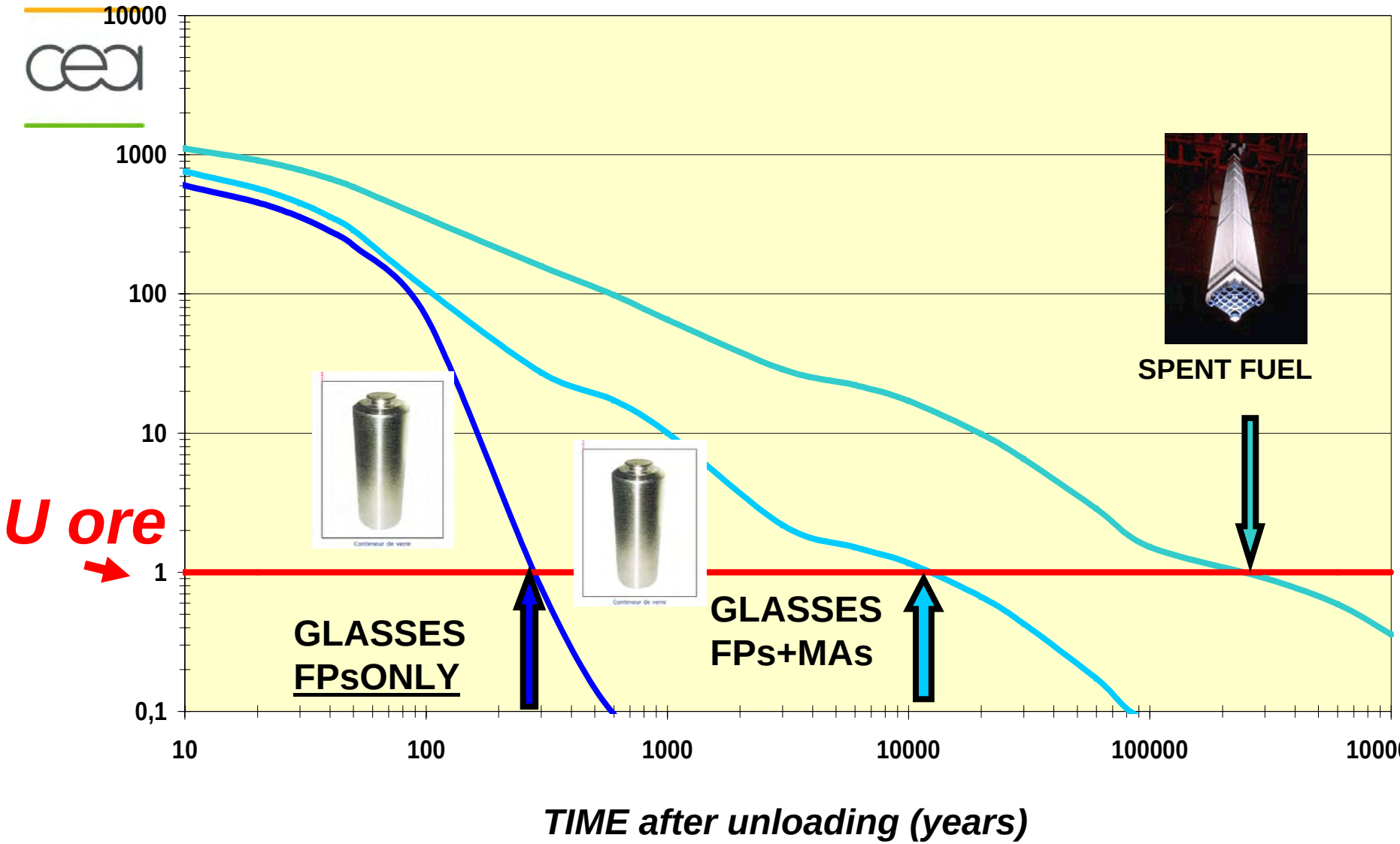
1 µm/50d at 50°C

1 µm/1000 years at 25°C

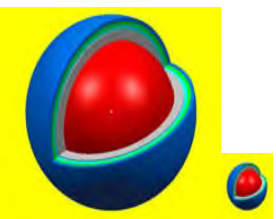
LONG TERM BEHAVIOR OF NUCLEAR GLASSES

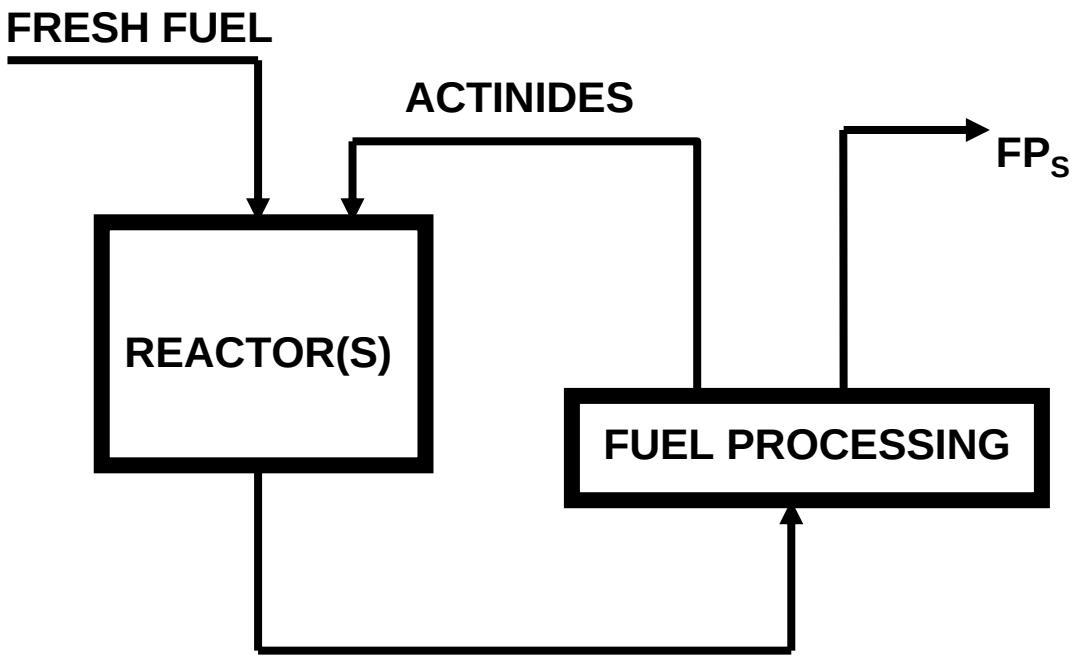


FINAL WASTE RADIOTOXICITY



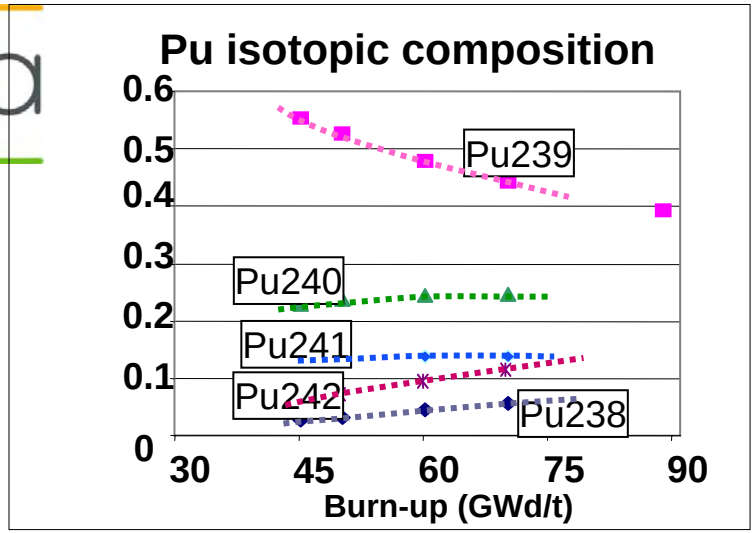
RECYCLING ACTINIDES : *WHAT TRENDS FOR R&D?*

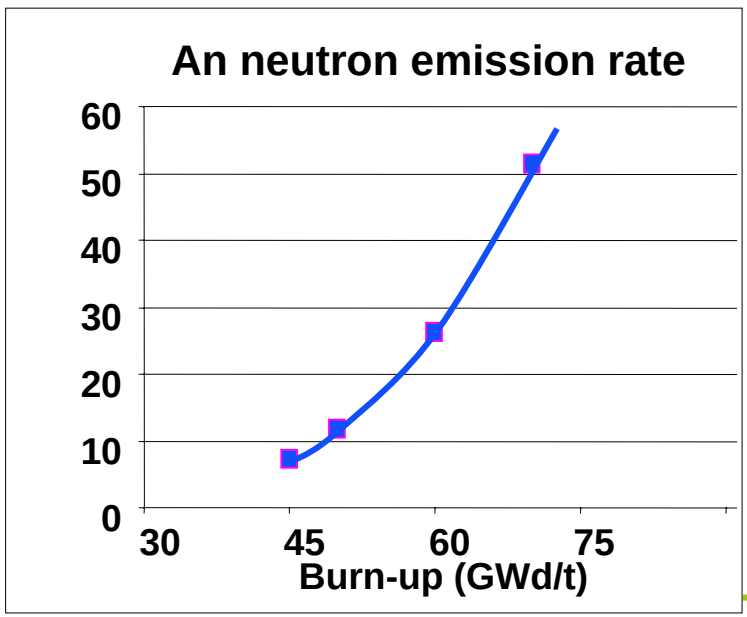




ADAPT, IMPROVE, COMPLETE…

RESISTANCE VS. PROLIFERATION RISKS





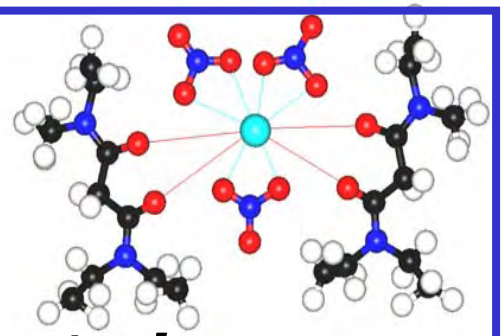
Recycling (and burning) plutonium :

- decreases its « *strategic value* »

- can decrease its « *accessibility* »

WHAT *PROCESSES* ?

- **SOLVENT EXTRACTION**
  - *high separation yields !*
  - *low amount of secondary waste !*



- *PYROCHEMICAL PROCESSES ?*

- *OPEN FOR INNOVATIVE « CHEMICAL SOLUTIONS » !...*

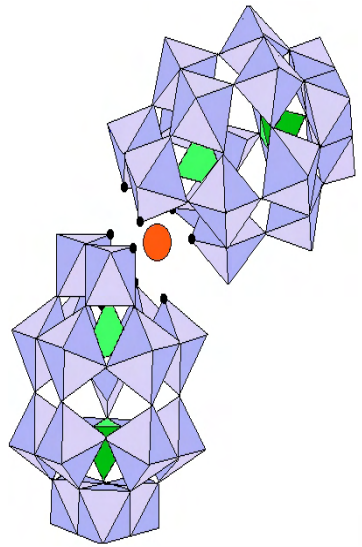
« *NUCLEAR* » CHEMICAL ENGINEERING

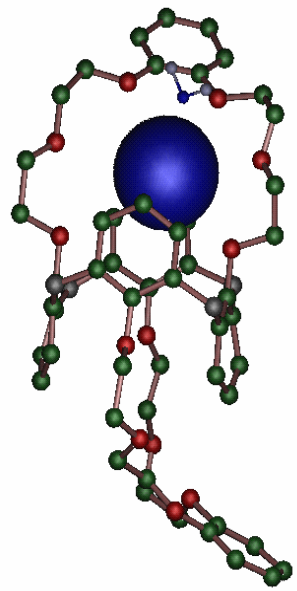
- **HIGH-LEVEL *RECOVERY YIELDS* REQUIRED**
- **HIGH-LEVEL *PURIFICATION FACTORS* REQUIRED**
- **COMPLEXITY / *DIVERSITY OF FPs***
- **VERY SEVERE *CONSTRAINTS***

(radiosensitivity, reliability, secondary waste)

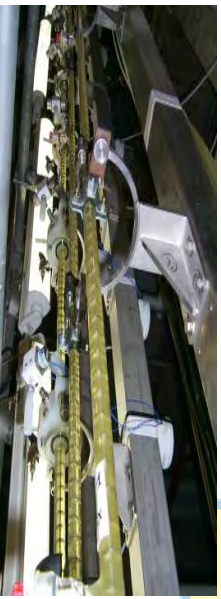
NEW EXTRACTANTS FOR An RECOVERY: MAIN CRITERIA FOR DESIGN

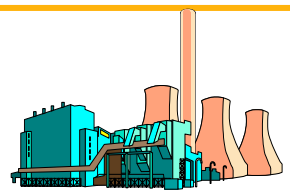
- **Ability to separate**
  - *Affinity*
  - *Selectivity*
  - *Reversibility*
- **Medium effects**
  - *Solubility*
  - *Stability / hydrolysis, radiolysis*
- **Industrialization**
  - *Kinetics*
  - *Physical properties*
  - *Cost*
- **Secondary waste minimization**





MINOR ACTINIDE RECOVERY: *A POSSIBLE PATHWAY*



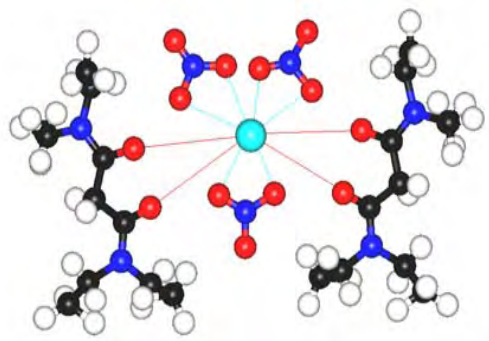


Spent Fuel

PUREX

U, Pu

Np



Two step strategy

Fission Products

DIAMEX

CO-EXTRACTION of MAs and Ln

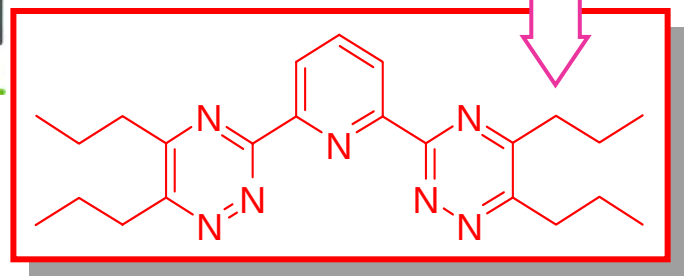
Ln

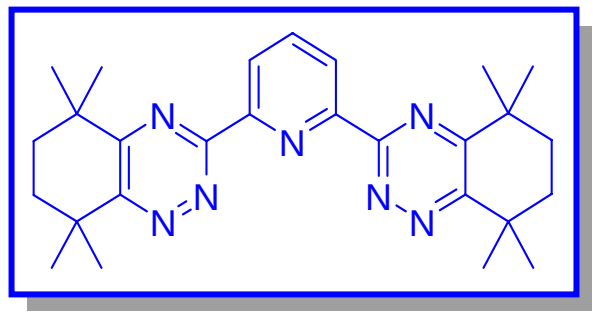
SANEX

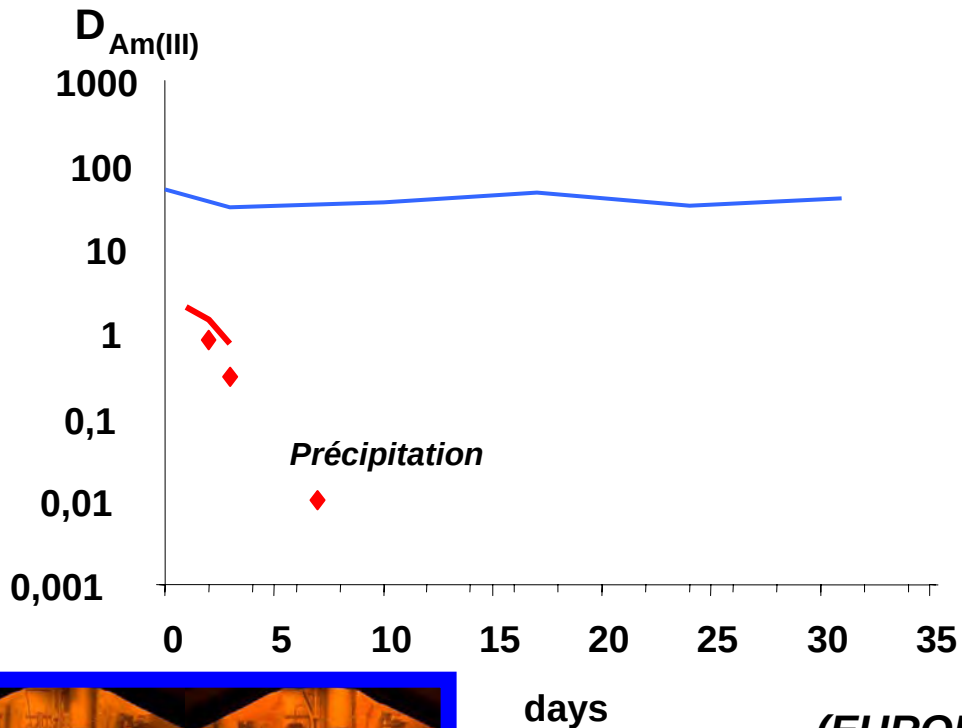
Am, Cm

SEPARATION of Mas from Ln

EXTRACTANT's STABILITY



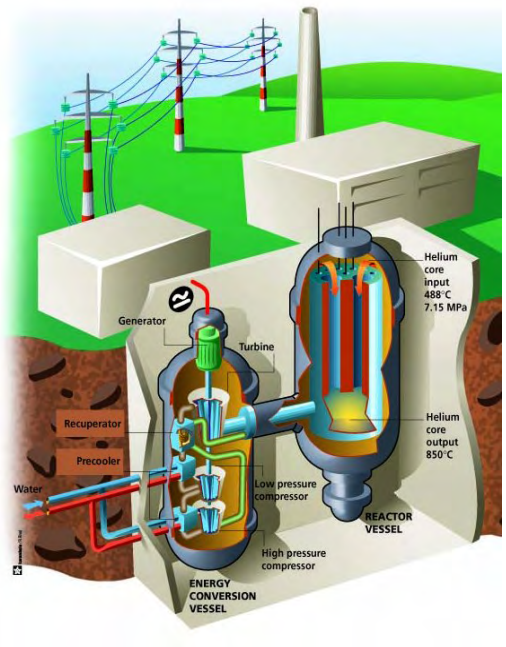




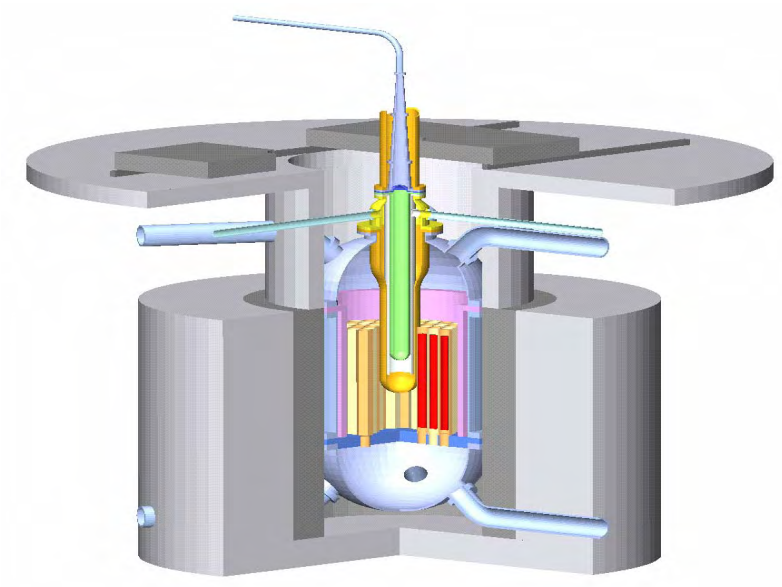
(EUROPART project, PCRD 5th)

RECYCLING MINOR ACTINIDES

Nuclear Power Plants ?



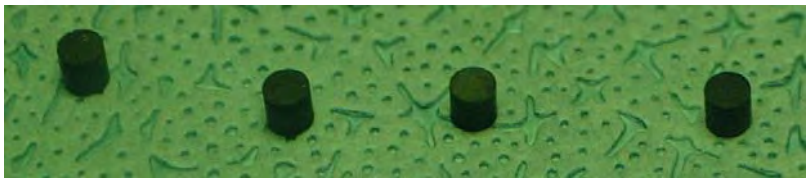
Dedicated Devices ?

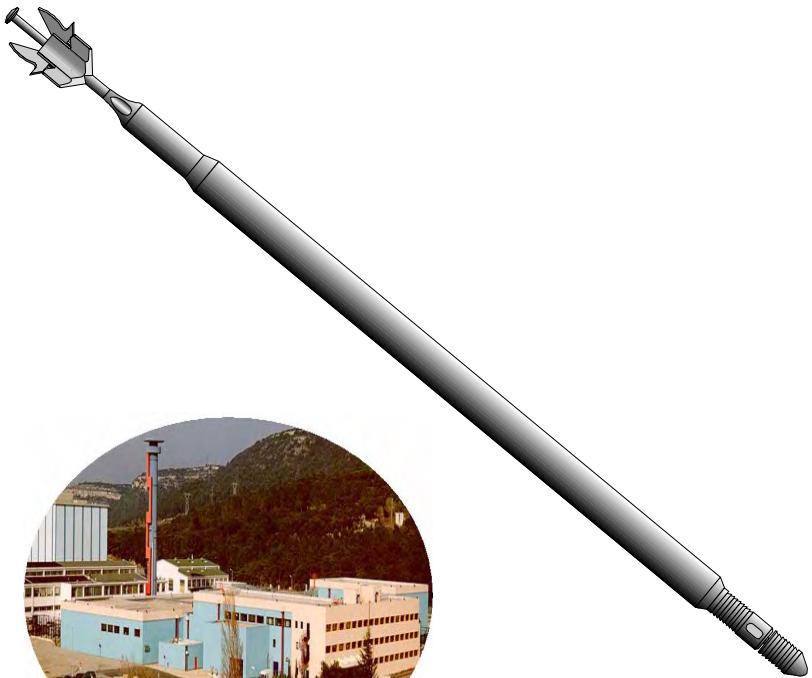


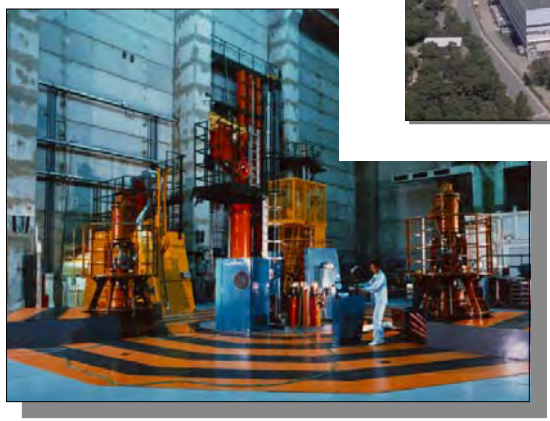
-Homogeneous (in the fuel) ou <u>Heterogeneous</u> (dedicated « targets ») ?

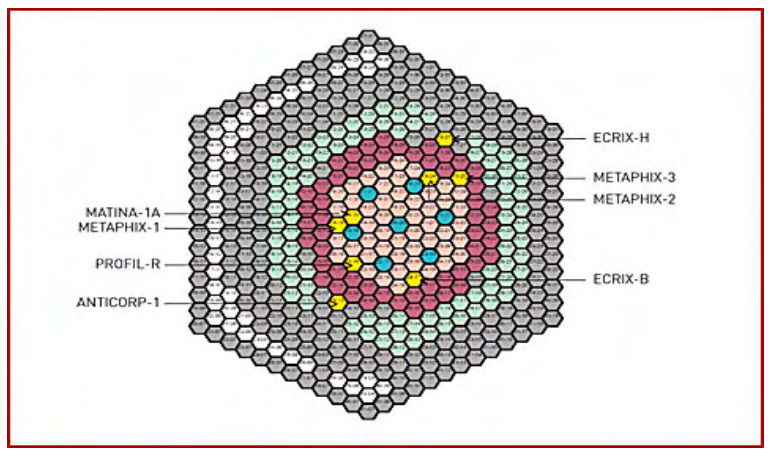
- The <u>FUEL</u> ?

M.A. « TRANSMUTATION » EXPERIMENTS

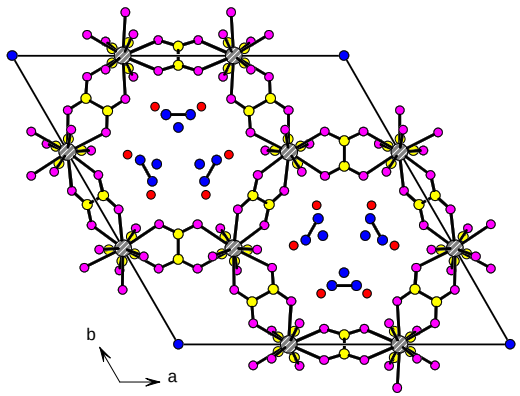


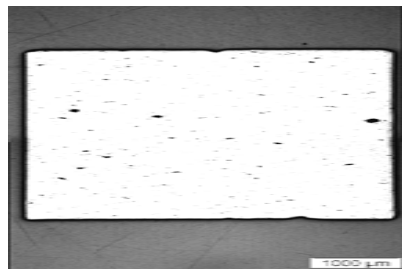






NEW PROCESSES FOR *POLYMETALLIC* FUELS?





Uranium-plutonium-(Mas)
co-precipitation

Homogeneous mixed oxide fuel

or other innovative fuels ?

en résumé …

- ***Nuclear Fuel Cycle*** **is a wide and particular field for chemistry : many successive transformations, under severe constraints and high-level performance requirements**

- ***Actinide recycling*** **appears an obvious need for *sustainable* nuclear systems.**

- ***Many diverse options are still open*** **: here is a wide frame both for *basic research* and *innovative technologies* development in separation chemistry!**