The Closed Fuel Cycle and Non Proliferation Issues

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The Closed Fuel Cycle

A condition for sustainable development of nuclear energy :

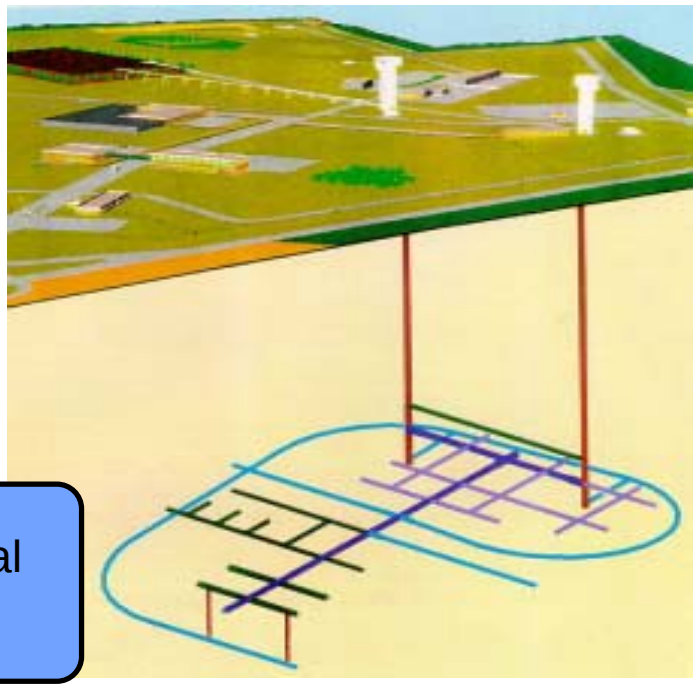
- to avoid any geopolitical tension in the use of uranium resources

- to reduce the burden associated to long term waste management

- to burn all fissile elements, thus offering a theoretically good proliferation resistance.

Nonproliferation : to burn or to bury

PHENIX fast reactor



Deep geological disposal

Non Proliferation Issues

Several issues related to the closed fuel cycle:

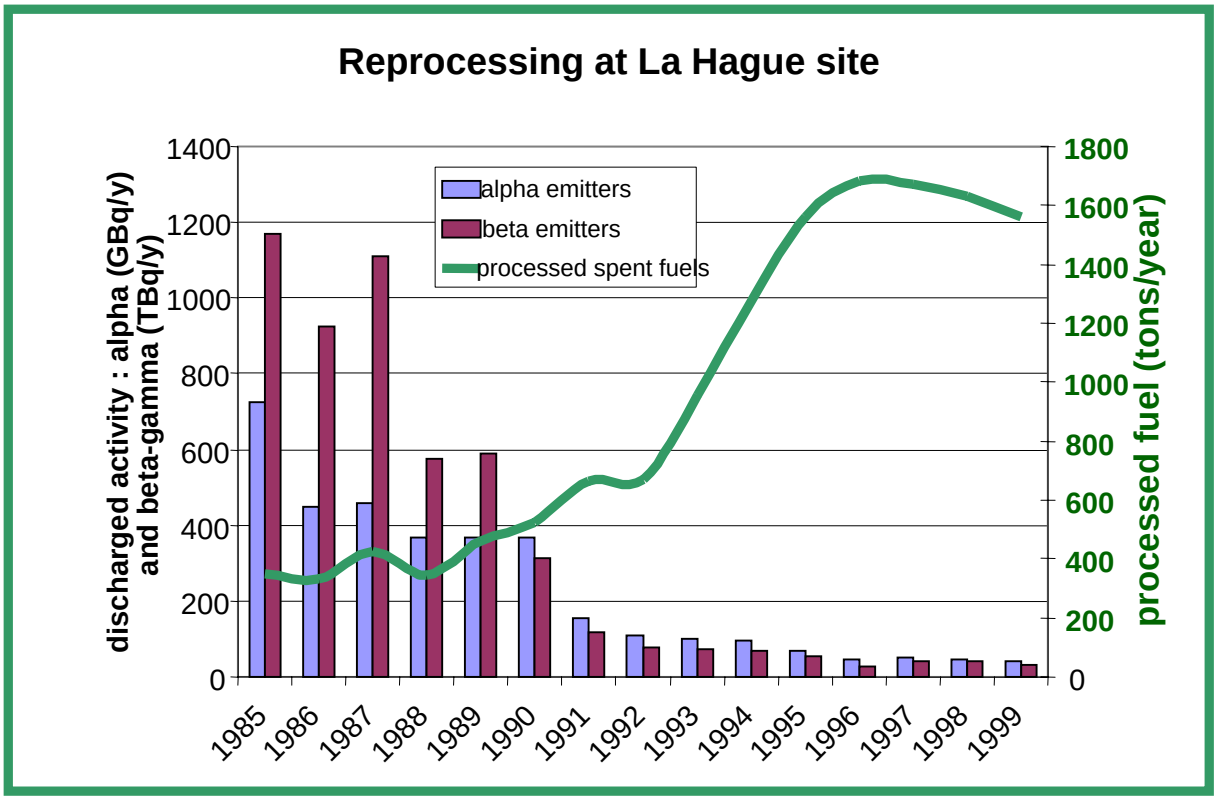
- **reprocessing plant implementation**
- **plutonium or other materials on shelves**
- **transportation of plutonium.**

Reprocessing, the French industrial experience

More than 15 000 Tons of fuel reprocessed at La Hague UP2 & UP3 plants

 # 1600 tons/year reprocessed since 1995

Reprocessing, the French industrial experience



Low environmental impact, in constant decrease

MOX fuel fabrication

100 tHM/year of MOX fuel manufactured at MELOX Plant

Since 1987, 1800 MOX fuel assemblies
delivered by Fragema

Recycling plutonium in LWR

THE EXPERIENCE WITH MOX FUEL

20 French, 2 Belgian, 3 German reactors loaded with MOX

2 Reactors (Cruas 3 & 4) loaded with reprocessed uranium

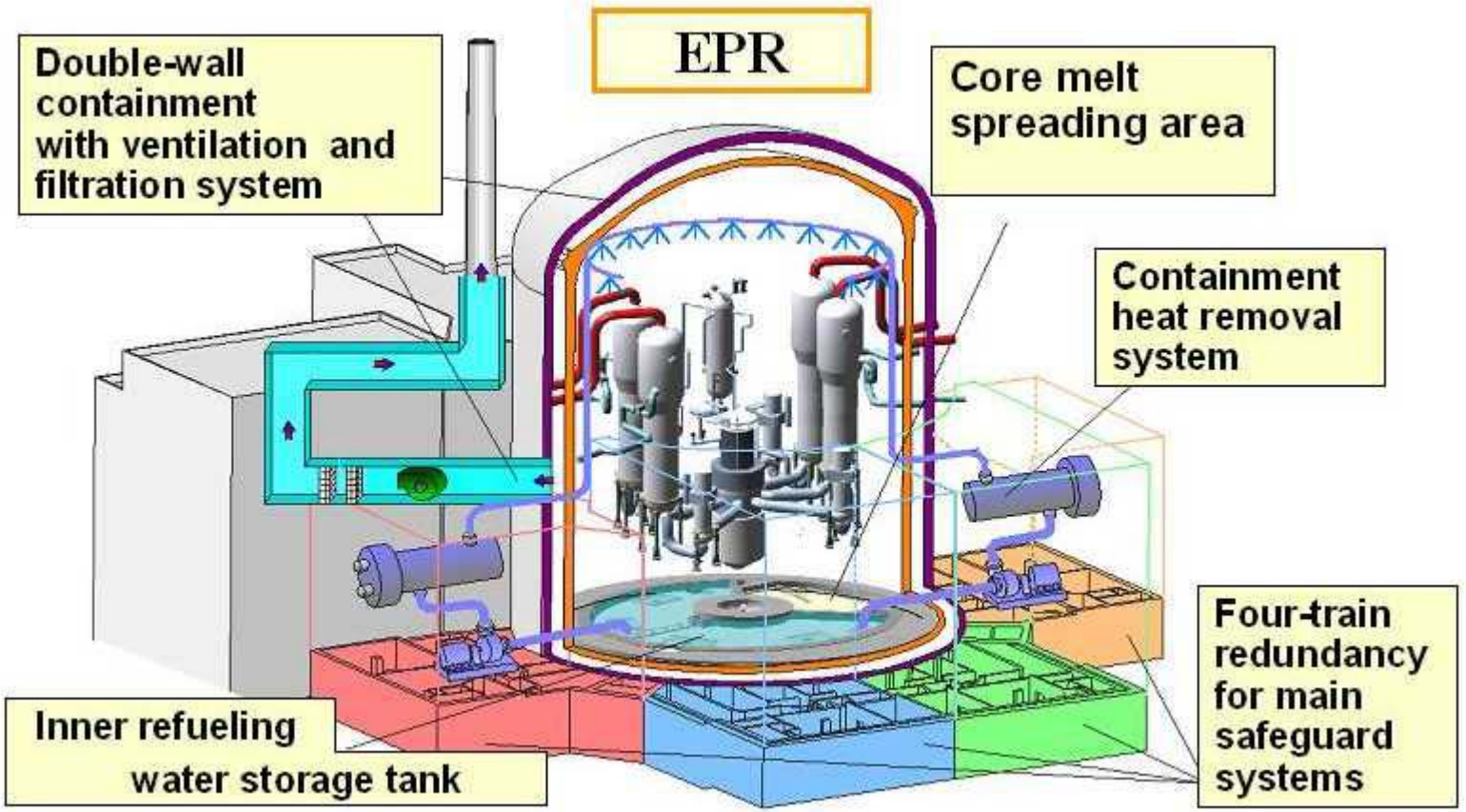
Fuel Cycles and Proliferation Resistance

➢ Classical PUREX/MOX strategy

- European/Japan approach / implemented by national companies
- Risk of proliferation associated to current industrial treatment and recycling is not underestimated today (meets IAEA / Euratom controls and requirements)
- Until now, no wrong use of nuclear materials coming from commercial treatment and recycling
- Civilian Pu is not attractive for making a nuclear head. HEU is more attractive and affordable than Pu, enrichment technologies are easier to afford than treatment technologies and processes
- Closed cycles (Vs Once-through and spent fuel geological disposal) : a better option to recycle and burn Pu (under today's IAEA control) than to leave « Pu mines » to our future generations

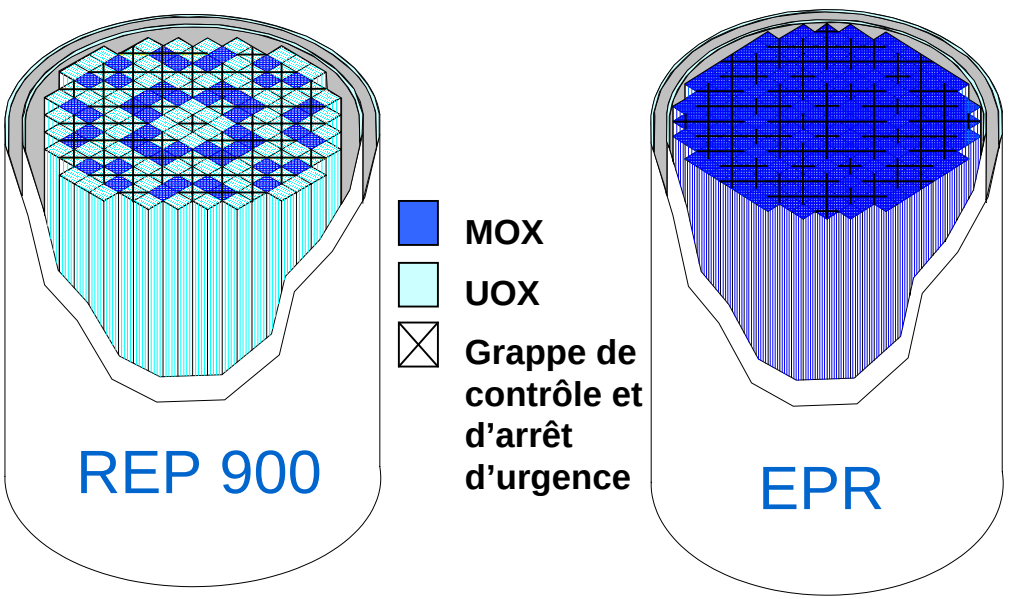
Light Water Reactors : Generation III

Framatome – ANP : EPR



The EPR is highly flexible and consistent with any types of Fuel Cycles

Capacity to load up to 100% MOX Core



An enhanced capacity to burn Plutonium

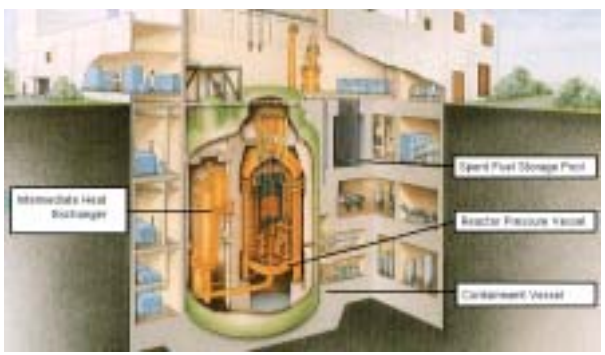
Plutonium annual balance Kg Pu/year

- REP 900 UO_2 : + 200
- REP 900 MOX : 0
- EPR 100% MOX : - 670

Gen IV : paves the way for a sustainable nuclear energy

Ensure energy needs are met in the long term without emitting greenhouse gases

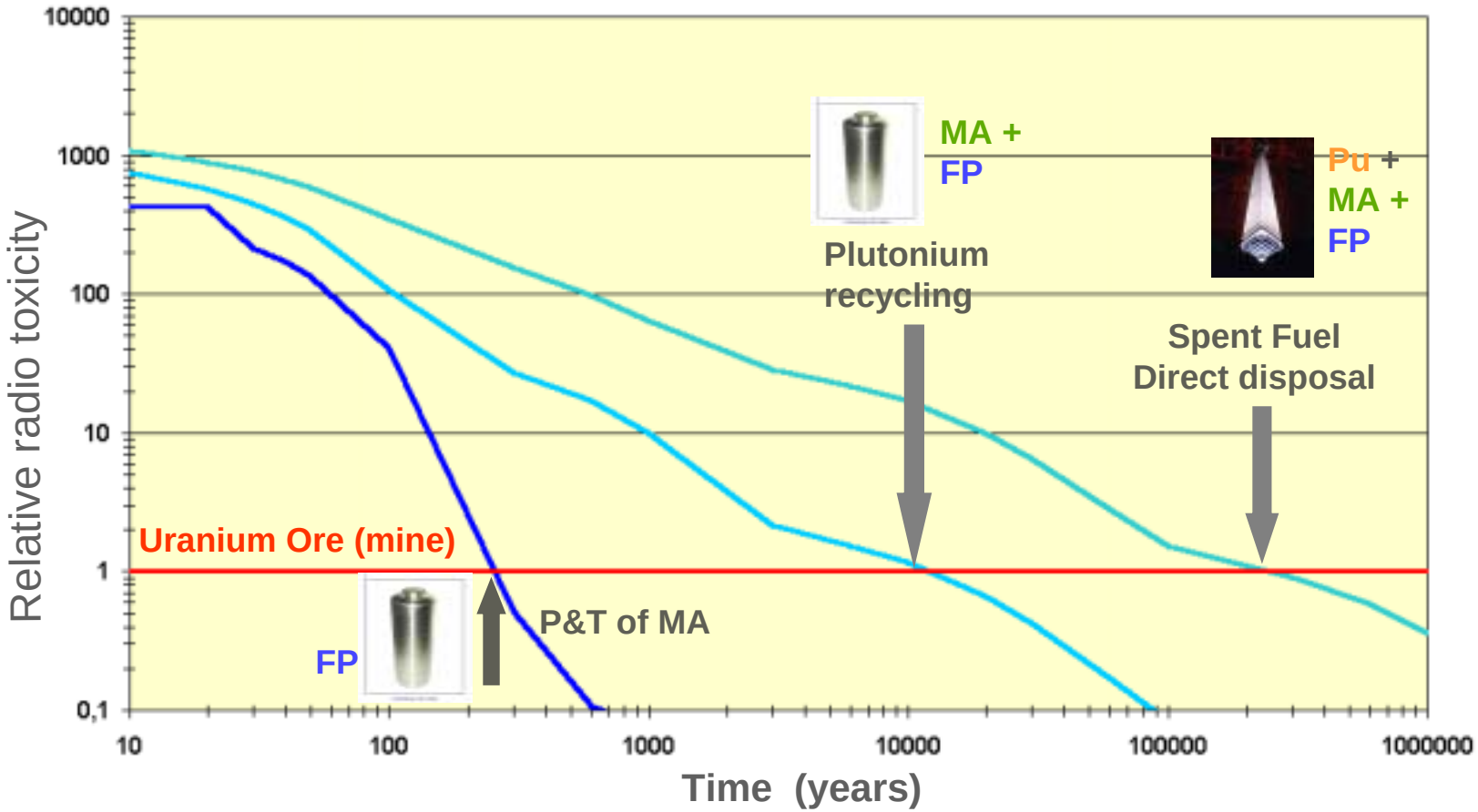
- **Gradual improvements**
  - Economic competitiveness
  - Safety and reliability
- **Significant steps forward:**
  - Saving of natural resources
  - Waste minimization
  - Security: non-proliferation, physical protection
- **An opening to other applications:**
  - High temperature heat for industry
  - Hydrogen vector
  - Drinking water



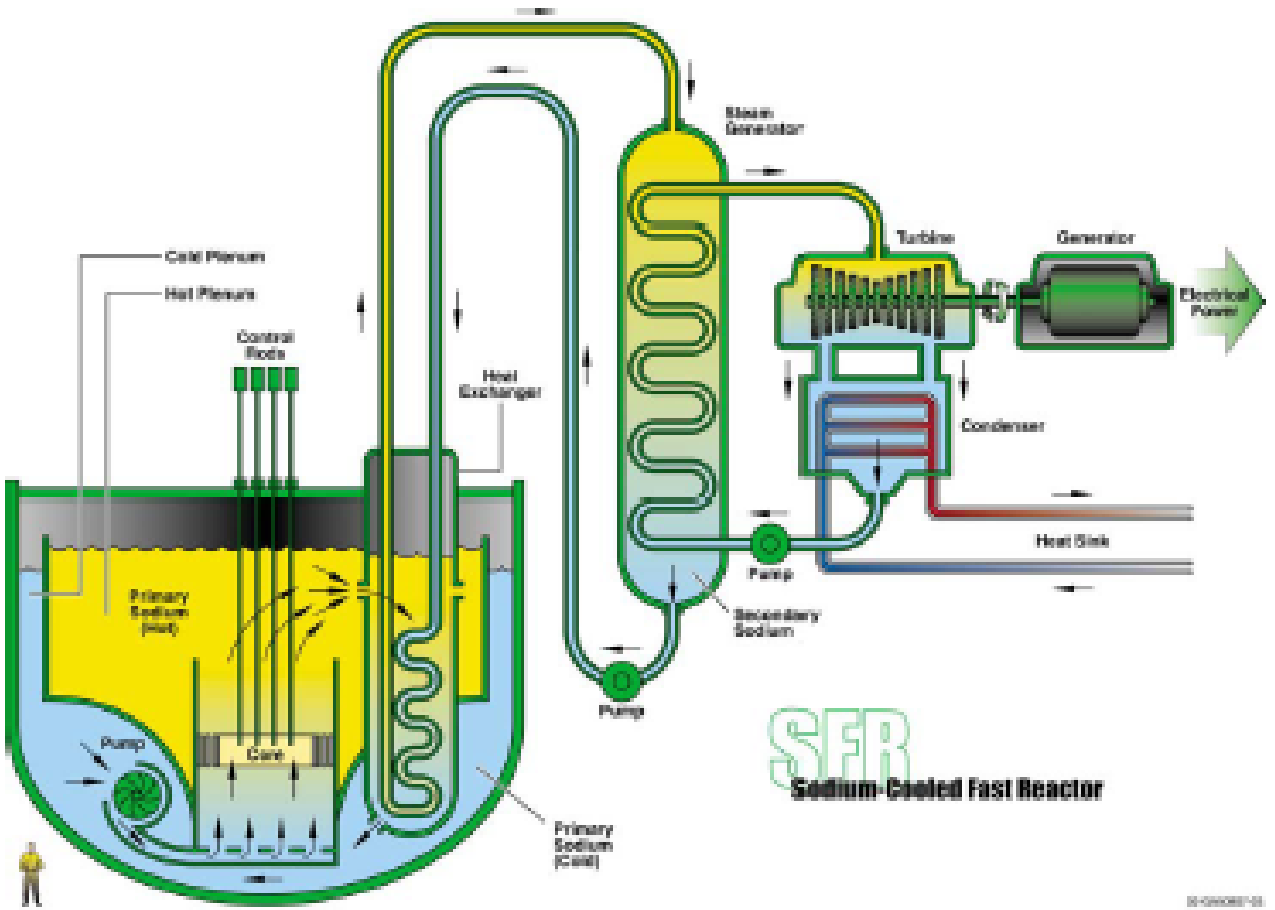
Waste management

- **A key problem for future deployment of nuclear power**
- **Direct disposal of spent fuels cannot be a sustainable solution**
- **To develop closed fuel cycles requires technologies and organization**
- **Non proliferation issues should be considered from the beginning**
- **Global recycling of all the actinides appears the best solution and is a requirement for future fast reactors**

Fast Reactors : Waste minimization

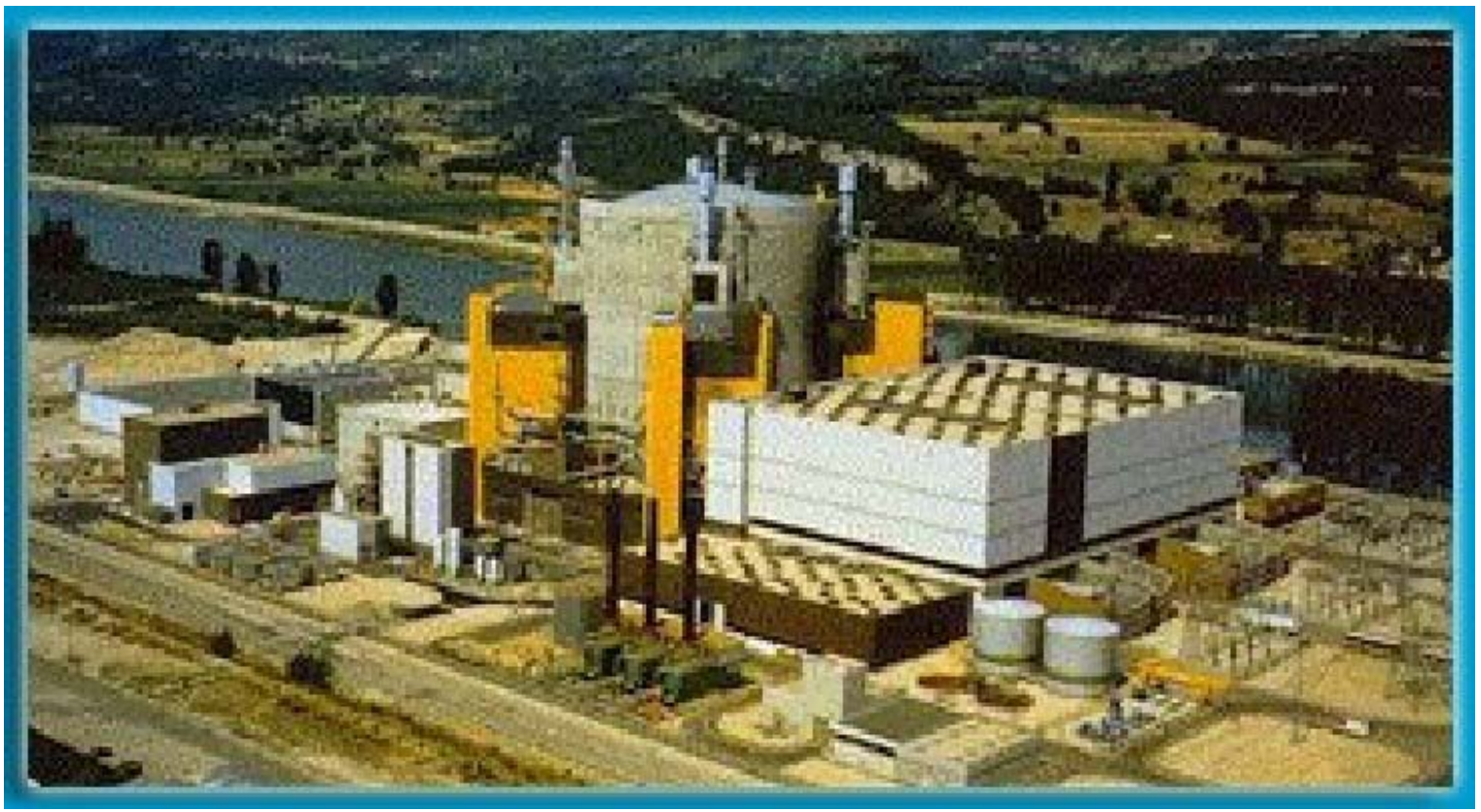


The pool design

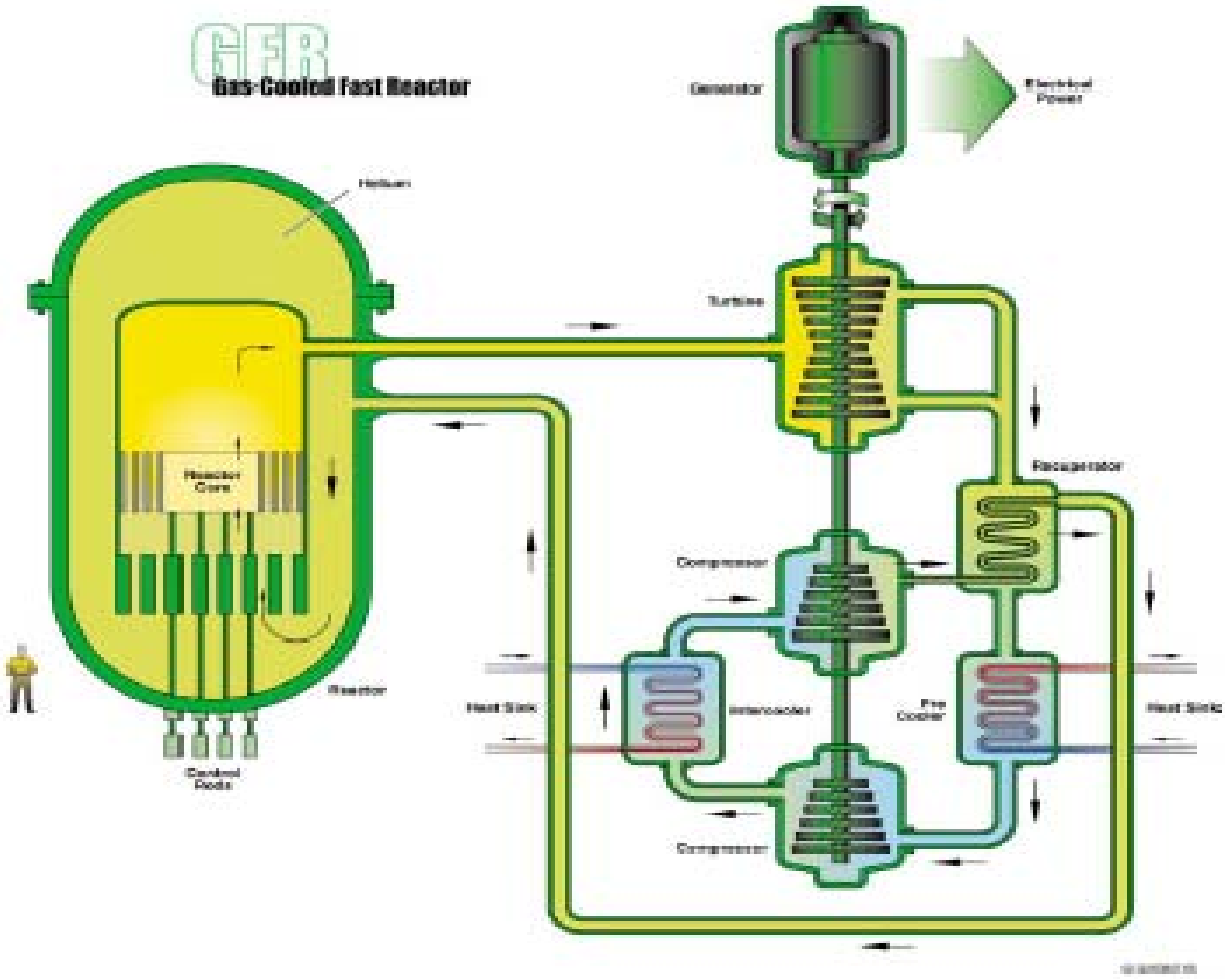


SUPERPHENIX

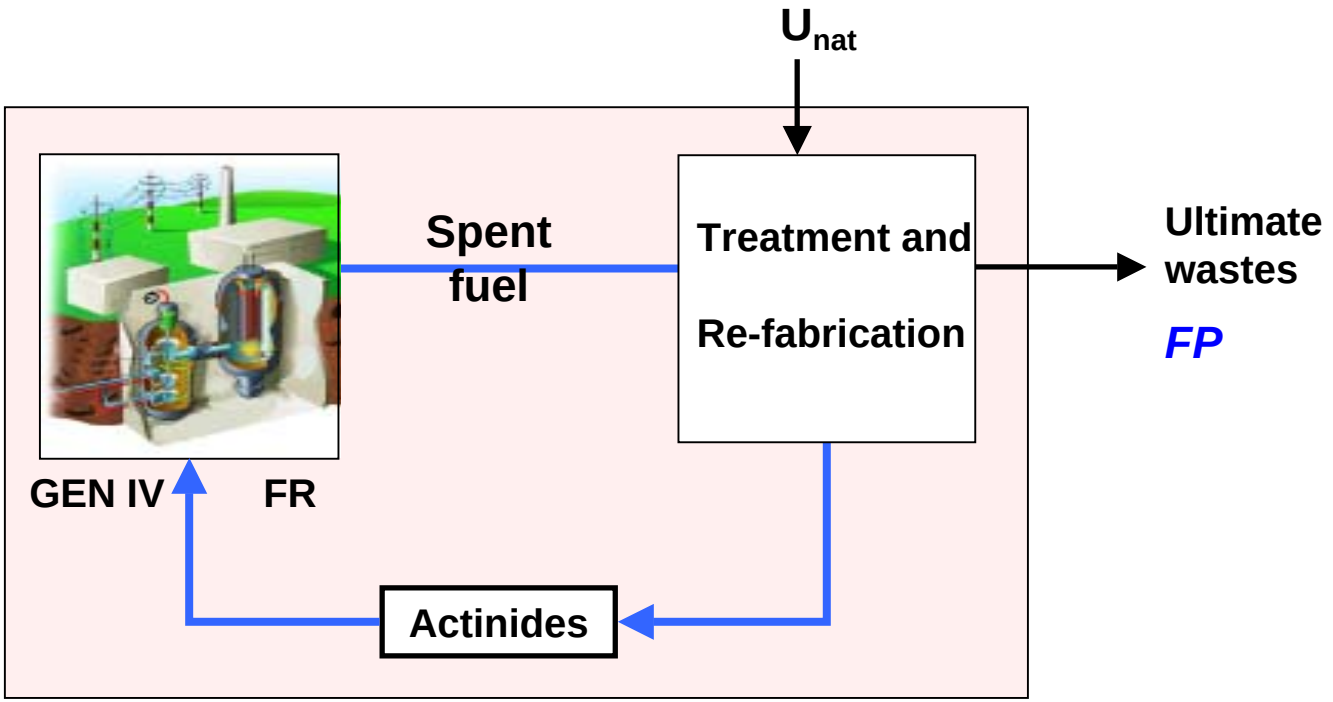
A 1200 MWe plant built at Creys-Malville (France)
First criticality: 1985; Shutdown: 1997



GFR Gas-Cooled Fast Reactor

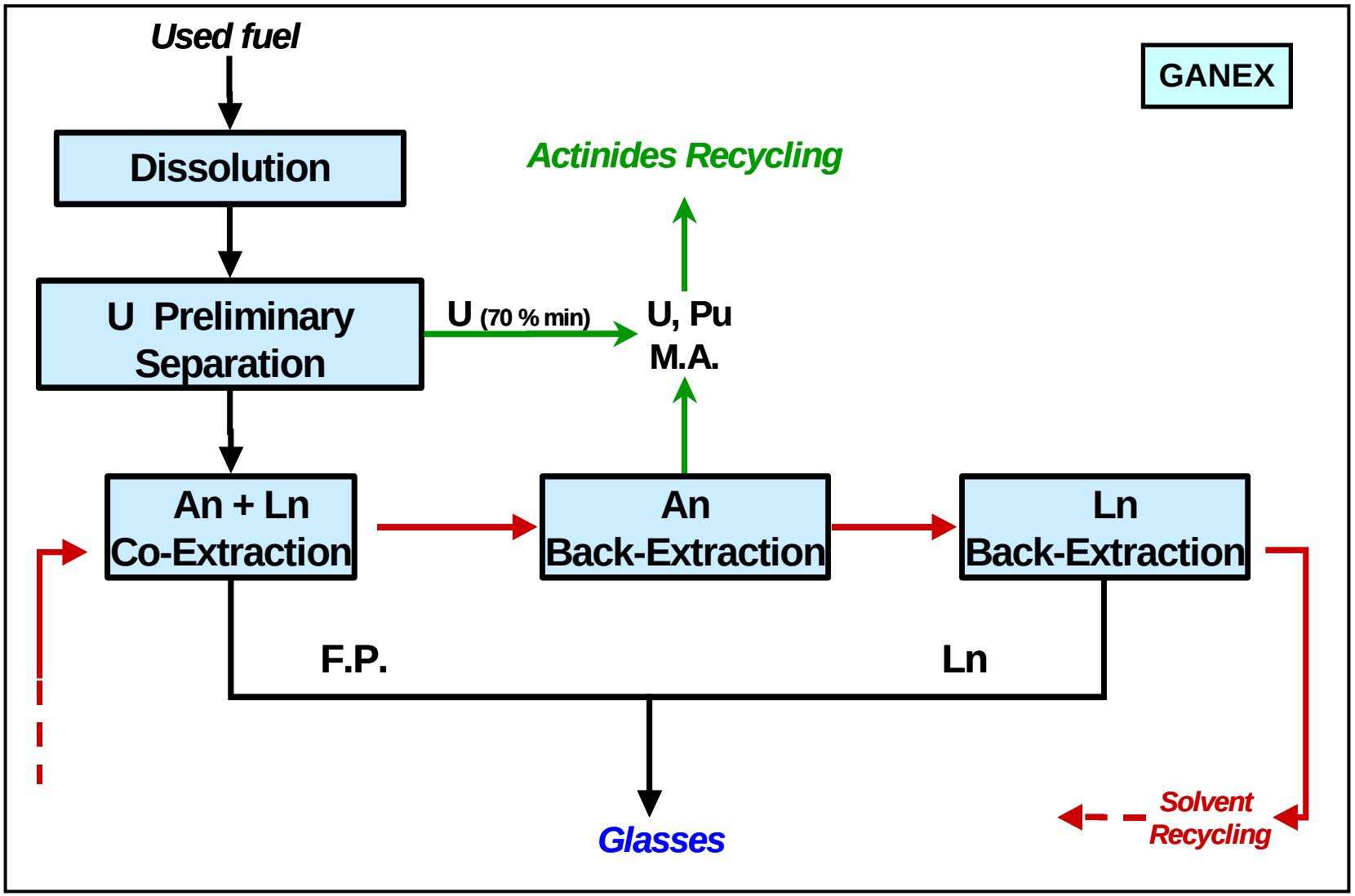


Gen IV Systems based on a global actinides recycling



- **A drastic minimization of ultimate wastes :**
  - **very small volumes, heat reduction**
  - **hundreds of years compared to hundreds of thousands**
- **An optimal use of energetic materials**
- **An increased resistance to proliferation**

Grouped Actinides Extraction : the GANEX Process



The Closed Fuel Cycle : A Path Forward

In the short term

- **Mono-recycling of plutonium in existing light water reactors:**
  - **to limit the growth of plutonium inventory,**
  - **to allow the management of ultimate waste from uranium spent fuels,**
  - **to concentrate in MOX spent fuels the plutonium available for future deployment of fast reactors**

  - **existing industrial reprocessing plants,**
  - **an already large experience with MOX fuels,**
  - **plants operated under international safeguards.**

The Closed Fuel Cycle : A Path Forward

In the near future

- **Improvements with Gen III light water reactors:**
  - **more flexibility for the use of MOX fuels,**
  - **possibility of reducing the plutonium inventory if the deployment of fast reactors is delayed.**

- **Demonstration of the potential of fast reactors:**
  - **for burning plutonium and other actinides,**
  - **Phenix and Superphenix experience,**
  - **a full scale demonstration in Monju…**

- **Design of Gen III industrial plants for treatment and recycling:**
  - **The only end-product should be a reactor fuel**

The Closed Fuel Cycle : A Path Forward

In the longer term

- **Deployment of Gen IV fast reactors:**
  - **initially fueled with plutonium and minor actinides coming from the treatment of MOX spent fuels,**
  - **breeding gain adjusted according to the needs of nuclear energy.**

- **Industrial implementation of the global actinide recycling:**
  - **no more separated elements (plutonium or others),**
  - **ultimate waste containing essentially fission products,**
  - **transportations limited to highly radioactive fuels**

- **Safeguards measures mainly oriented towards:**
  - **The accountancy of fuels,**
  - **The integrity of treatment processes.**