DE LA RECHERCHE À L'INDUSTRIE

FRENCH R&D PROGRAM ON SFR AND THE ASTRID PROTOTYPE

FR13 Conference

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www.cea.fr

WHY TO CHOOSE A FAST NEUTRON REACTOR?

Three main reasons:

- Mastering, through recycling, the growth of Plutonium inventory
- Excellent use of uranium resource
  - Unlike reactors currently in operation or construction worldwide, that use only about 1% of natural Uranium, Fast neutron Reactors are able to use more than 80% of the Uranium resource.
  - The current stockpile of depleted Uranium available in France could feed the current needs of electricity production for several 1000 years.
- Ability to transmute and burn minor actinides

A CONVENIENT TECHNOLOGY

Two types of Fast Reactor have been selected in France:

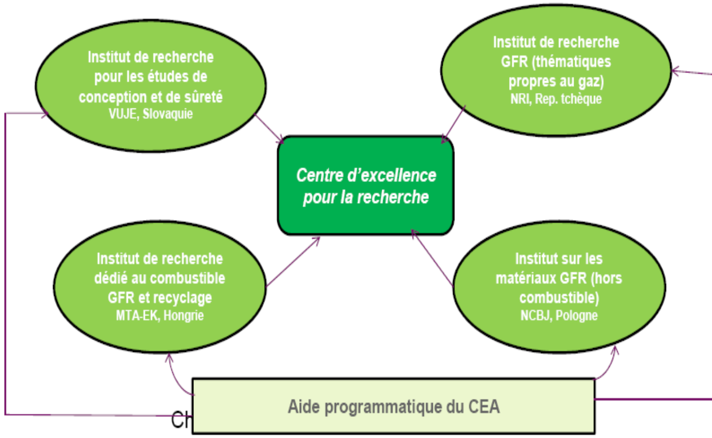
- Cooled by gas
  - The ALLEGRO Project

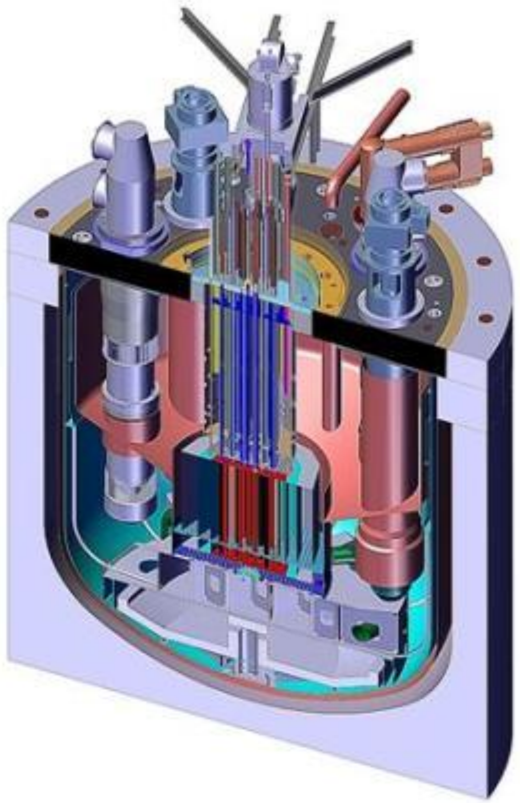
- Cooled by sodium
  - The ASTRID Project

GAS-COOLED FAST REACTOR DEVELOPMENT

- Gas-cooled Fast Reactors, a longer term option
  - Good potential, but important technological obstacles
    - Materials, Refractory Fuel, Safety
  - CEA focus its R&D on cladding and safety
- GFR embodied in the ALLEGRO project, in Europe
  - Establishment of a four Countries Consortium (Czech Republic, Hongary, Poland, Slovakia) to cover :
    - The construction of the reactor
    - The construction of the associated R&D capabilities (Centers of Excellence).

➡ ***CEA Closely associated to the consortium***



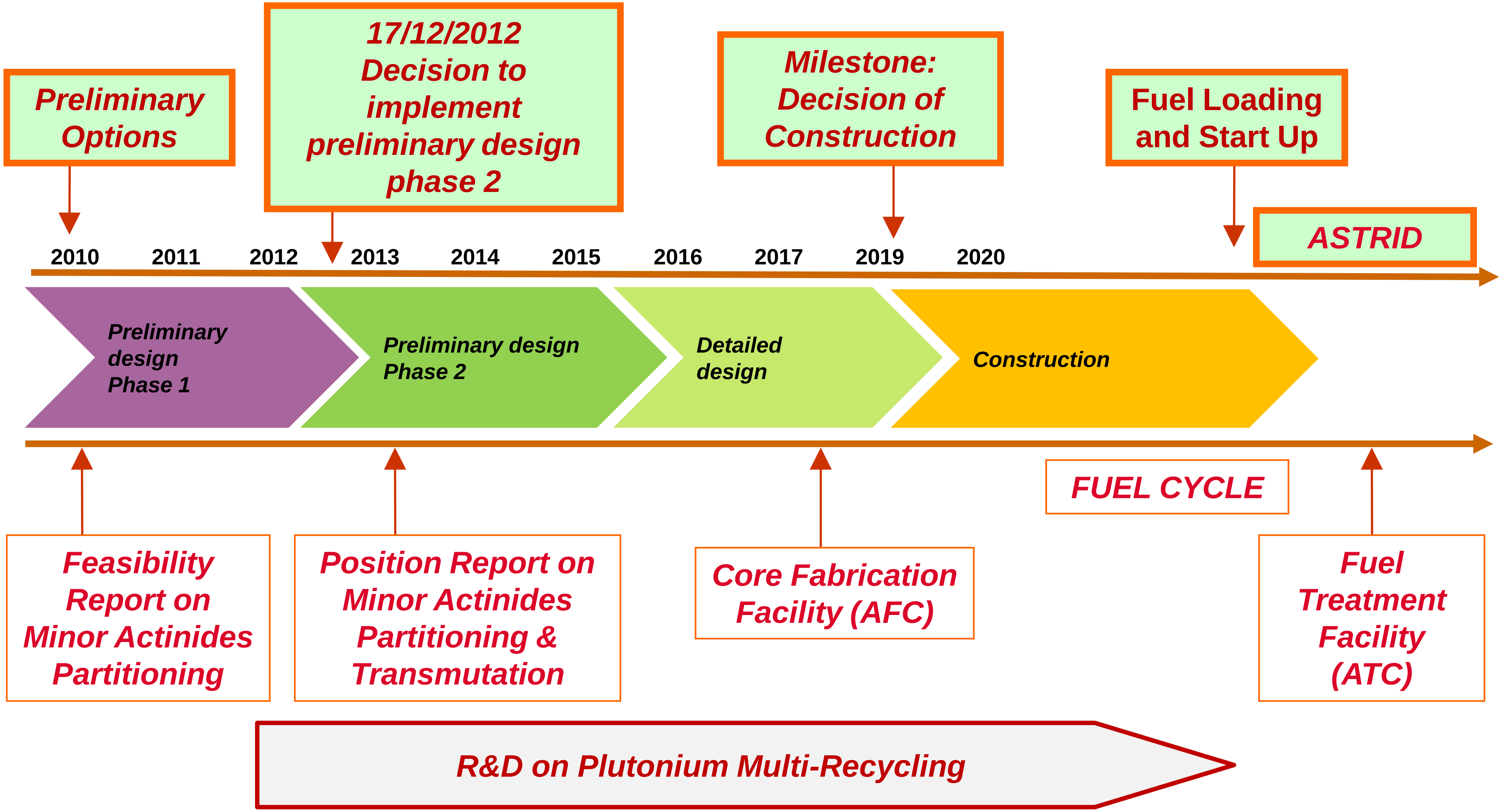


- ASTRID design studies
  - Integrated Technology Demonstrator
  - 600 MWe
  - 4th generation reactor

+ R&D

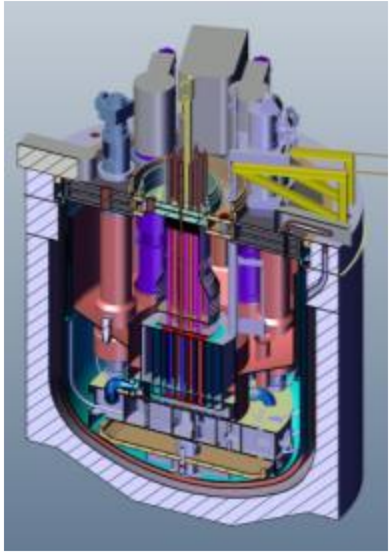
(Including fuel cycle)

ASTRID FUEL CYCLE SCHEDULE



ASTRID AND LESSONS FROM FUKUSHIMA ACCIDENT

- ASTRID will be designed using lessons learnt from the Fukushima-Daichi accident
- The design benefits of merits of pool-type Sodium-cooled fast neutron reactors
    - Favorable intrinsic features to cool-down the reactor: Large thermal inertia; Diversified heat sinks; Natural circulation; Ability to guarantee a minimum sodium level.



- Safety objectives of ASTRID are derived from the WENRA* document “Safety objectives for new nuclear power plants”.
    - It summarizes the highest safety standards, even for Fukushima-like initiators. Former ***Beyond Design Basis Accidents*** are included in the design.

**Western European Nuclear Regulators Association*

- Safety requirements are checked with the Generation IV International Forum Safety Design Criteria

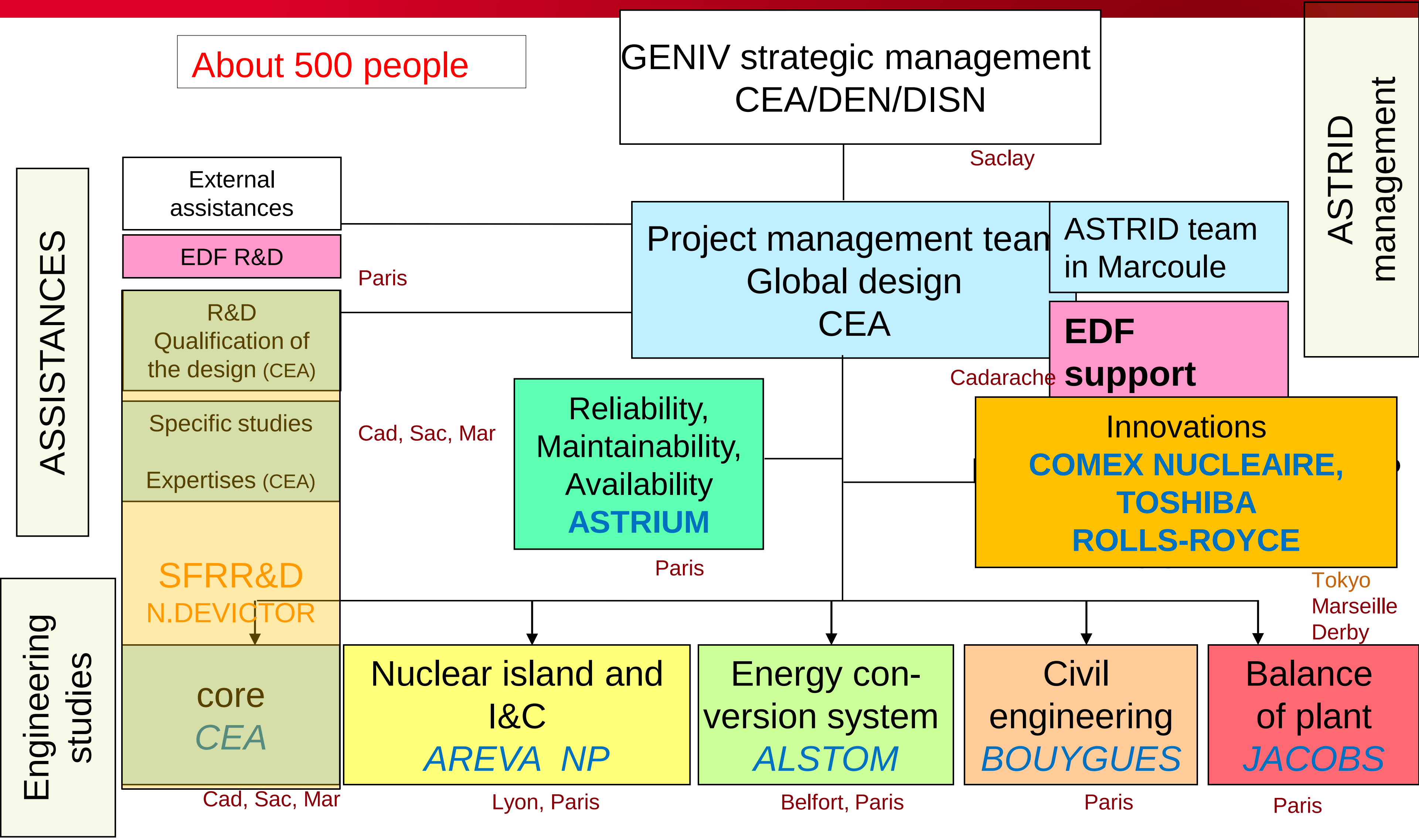
STRONG IMPROVEMENTS IN SFR DESIGN FOR ASTRID 1/2

Feedback of previous SFRs	R&D directions	ASTRID Orientations
Core Sodium voiding reactivity **→ Safety**	Optimization of core design to improve natural behavior during abnormal transients. Exploration of heterogeneous cores	CFV core (Patented in 2010): innovative approach, <u>negative</u> overall <u>sodium voiding reactivity</u> Better natural behavior of the core, for instance in case of loss of flow (e.g. due to loss of supply power)
Sodium-Water interaction **→ Safety - Availability**	Modular Steam Generators Reverse Steam Generators (sodium into tubes) Gas Power Conversion System (nitrogen in place of steam/water)	Limitation of total released energy in case of sodium-water interaction Limitation of wastage propagation Design studies conducted by ALSTOM. No show stopper.

STRONG IMPROVEMENTS IN SFR DESIGN FOR ASTRID 2/2

Feedback of previous SFRs	R&D directions	ASTRID Orientations
Sodium fire **→ Safety**	Innovative Sodium leak detection systems R&D on Sodium aerosols	Improving detection (Patent of detection system integrated in the heat insulator) Close containment (inert gas + restriction of available oxygen)
Severe accidents **→ Safety**	Core catcher Research on corium and sodium-corium interaction	Core catcher. Several possible locations (in vessel, ex-vessel or between the two vessels).
Decay heat removal **→ Safety**	Reactor vessel auxiliary cooling system (scaling rules)	Combination of proved Decay Heat Removal systems and Vessel Natural Air draft cooling
In-Service Inspection and Repair **→ Safety – Availability**	Simplification of primary system design ISI&R taken into account from the design stage New techniques : Acoustic Detection, Laser, CRDS Signal processing Ultrasound at high temperature, High temperature fission chambers, Optical Fibers, Flow meters for subassembly Remote handling for inspection or repair Under-sodium viewing	

ASTRID PROJECT INDUSTRIAL ORGANISATION



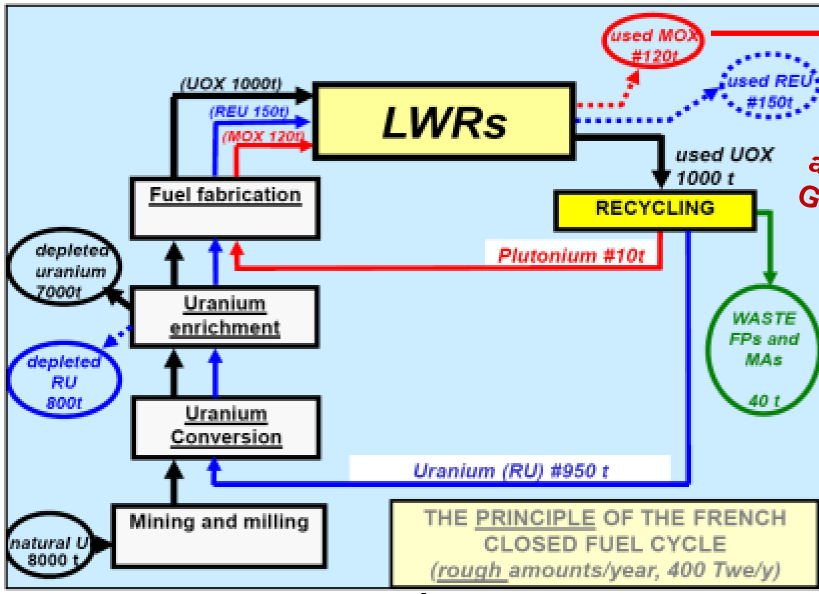
R&D COLLABORATIONS IN SUPPORT TO ASTRID

- Europe
  - EU Framework Program : Croscutting R&D on Core Safety, Fuel Safety, Instrumentation, Seismic Studies
- India
  - Cooperation focused on safety
- Japan
  - Trilateral with DOE **:** Advanced Material, Instrumentation, Thermohydraulic, etc :
  - Severe Accidents : Participation to Eagle Program
- Russia
  - Material test in BOR-60; Core physics in BFS; Possible Fuel Irradiation in BN-600
- USA
  - Trilateral with DOE **:** Material, Instrumentation, Thermohydraulic, etc
  - Core Safety Assessment Benchmarking
- China
  - Material Study (irradiation program in CEFR under assessment)
- Korea
  - Cooperation in the field of sodium technologies under assessment

Generation IV International Forum : involvment in GIF R&D projects (fuel, material, safety and operation….

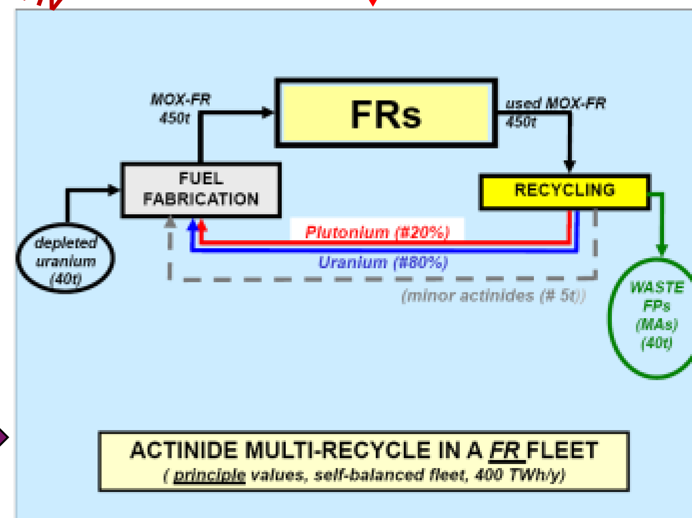
IAEA : through INPRO, safety requirements, scenarios ,

FROM LWRs RECYCLING TO FRs RECYCLING



Pu stored in MOX Spent Fuel recycled in MOX SFR to start the SFRs deployement

Current technologies: a bridge between GEN II/III and GEN IV



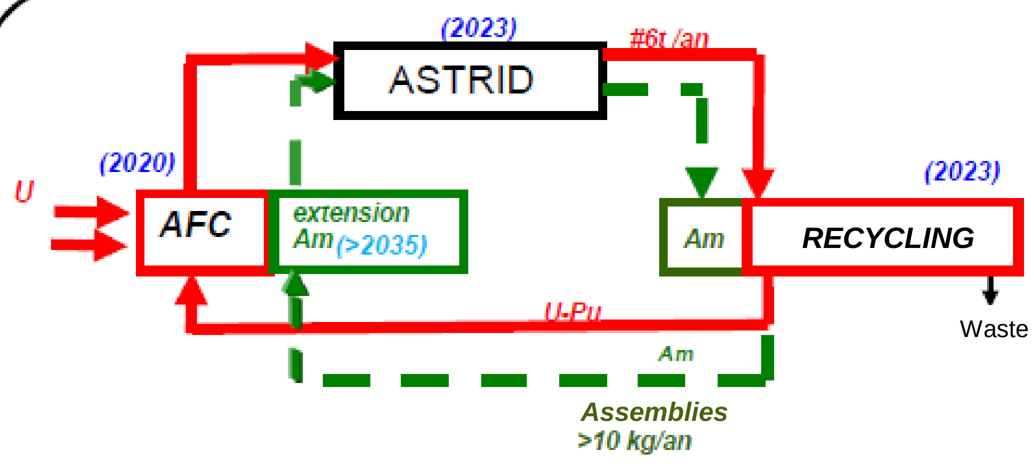
Scenario can be flexible

Both systems can coexist during a transition phase

- RNR merits as regards to fuel cycle
  - No front end steps and no enrichment technology
  - Use depleted U; Use Pu included in MOX Spent Fuel
  - Multi-recycling of Pu
  - Possible recycling of Minor Actinides

FUEL CYCLE FACILITIES FOR ASTRID

- ## ASTRID Fuel Fabrication Facilities
  - **AFC** Project (# 10 t/y), several scenarios under assessment
  - SFR closed cycle demonstration (U and Pu multi-recycling):
    - **ATC**, a Specific Engineering Scale Facility, or
    - adaptation of the La Hague Head End (shearing and dissolution)
  - M.A. transmutation demonstration: Extension of the AFC



The ASTRID Fuel Cycle

CONCLUSION

RAPSODIE
1967 - 1983
PHENIX
1973 - 2010
SUPERPHENIX
1985 - 1998
EFR
1988-1998
ASTRID
Commercial reactor

Thank you

Commissariat à l'énergie atomique et aux énergies alternatives
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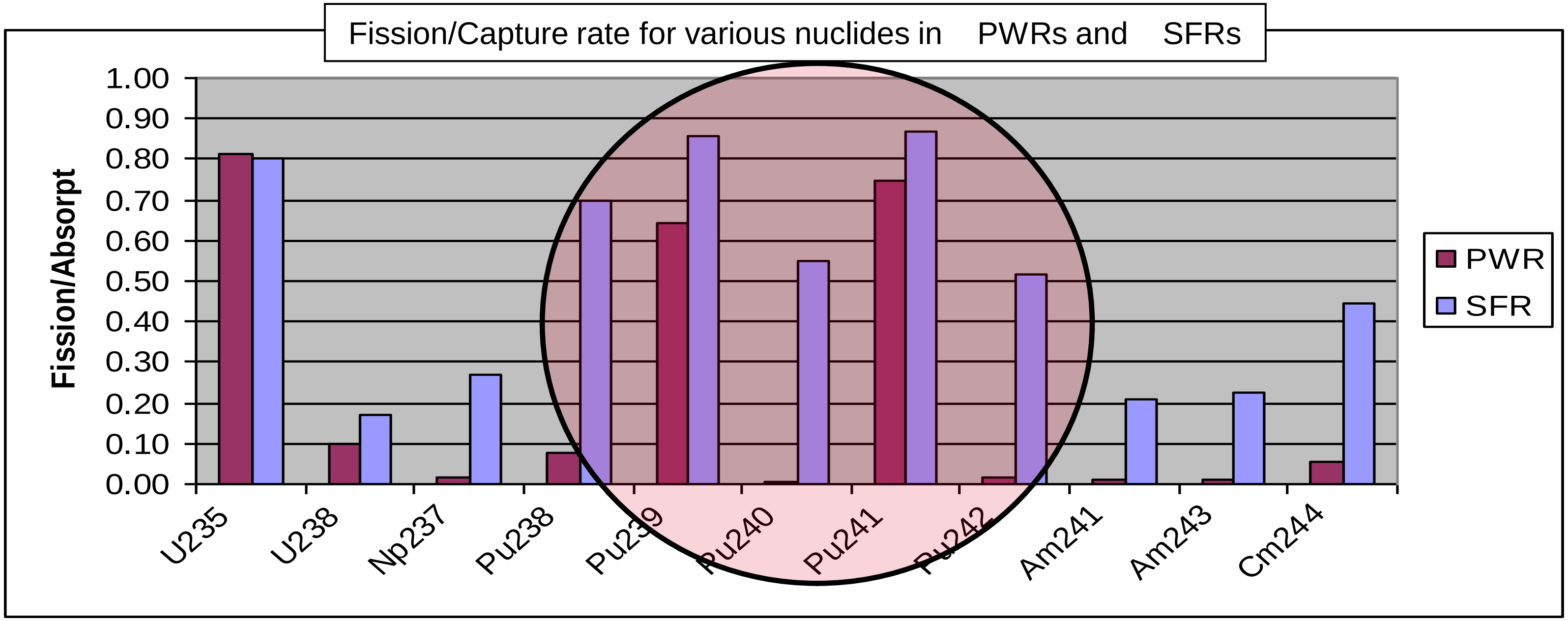
Nuclear Energy Division

1. KEEP ON RECYCLING

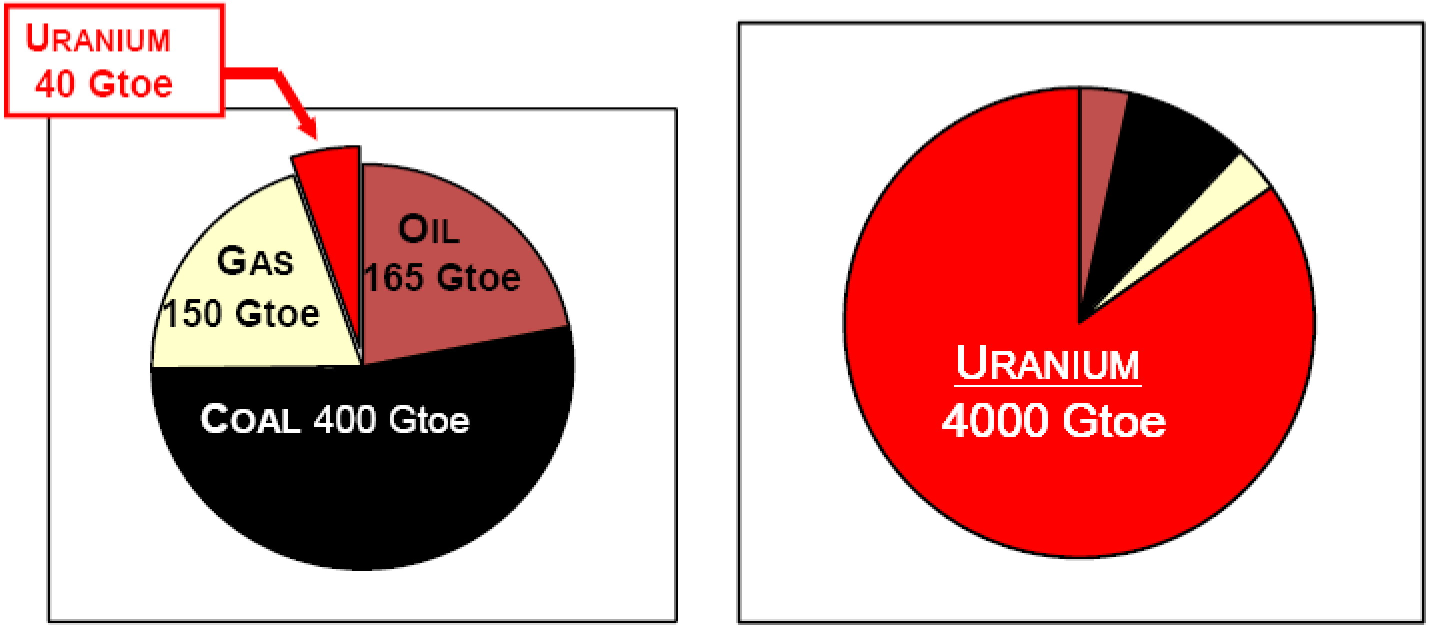
2. IN FAST REACTORS

Because of these main merits :

- EFFICIENT BURNING OF PLUTONIUM
- NO NEED FOR NATURAL URANIUM
- POTENTIAL FOR IMPROVING WASTE MANAGEMENT



A BETTER USE OF URANIUM 238



Uranium use in **current reactors**	Uranium use in **4th generation reactors**

Source : WEC, 2010 Survey of Energy. (Coal: 860 Gt, Oil: 163 Gt, Gas: 185 Tm3, Uranium : 3,5 Mt)

RADIAOCTIVE WASTE OF GENERATION IV SYSTEMS