Fast Breeder Reactor Development
EDF's point of view

N. Camarcat, J-M. Delbecq, J-F. Sauvage, D. Verwaerde, P. Berbey

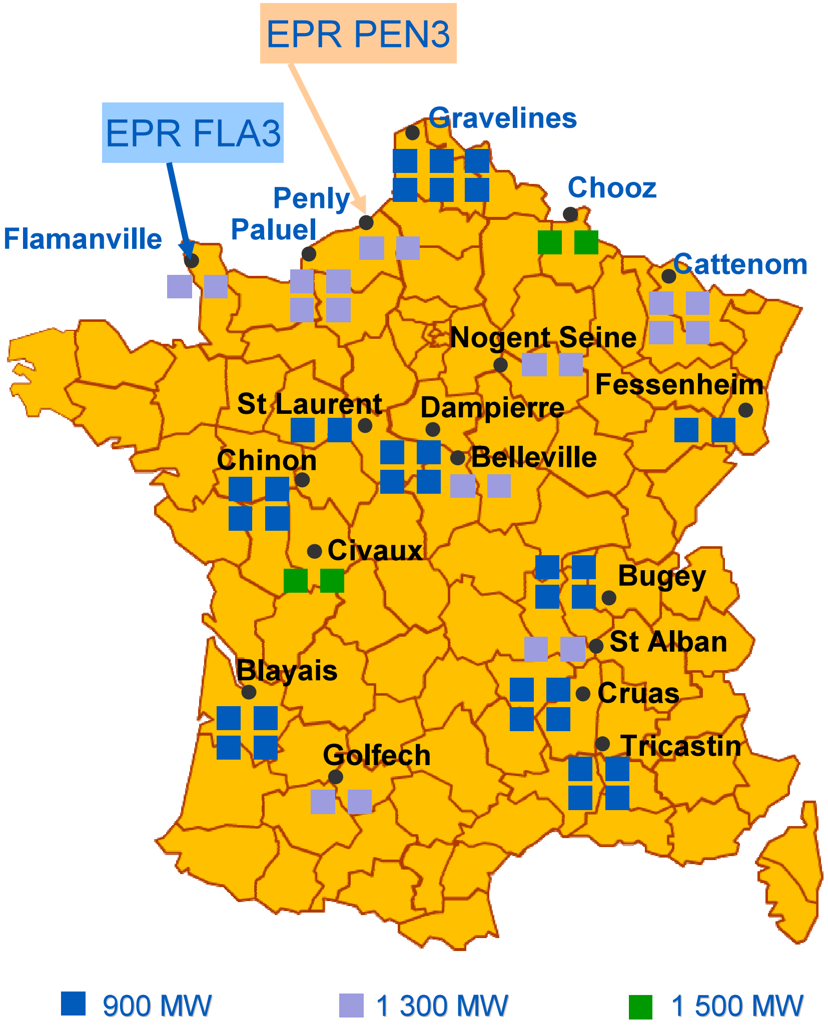
FR09 - KYOTO
December 7 – 11, 2009

CHANGER L'ÉNERGIE ENSEMBLE

Outlook

- Nuclear generation in France : the EDF fleet
- EDF's Strategy for its nuclear fleet
- EDF's point of view on Gen 4 SFRs
- EDF's first utility requirements for the industrial Gen 4 SFRs
- EDF's R&D program for the industrial Gen 4 SFRs
- The French SFR prototype and the R&D program
- A few utility requirements for the French SFR prototype
- Fuel cycle scenarios : EDF's point of view
- Conclusions and perspectives

Nuclear generation in France: the EDF fleet



- 58 Gen II reactors in operation
- Gen III: 1 being built (FLA3), 1 decided (PEN3)
- 19 sites
- A single technology: PWR (Pressurized Water Reactor)
- 3 main series of highly standardized units in operation:
  - 900 MW: 34 units
  - 1300 MW: 20 units
  - 1 500 MW (N4): 4 units
- Young fleet:23 years old in average
- Extensive operating experience: > 1350 reactor • years

EDF's strategy for its nuclear fleet

- **EDF aims at increasing the operating life of its Gen II reactors to 50 - 60 years**
  - a major engineering effort for the 900, 1300 MWe and N4 units
- **The renewal of the fleet with Gen 3 EPR**
  - Flamanville 3 is a reference EPR construction project – commissioning in 2012
  - EPR design life: 60 years ⇨ EDF expects to operate its PWR fleet well beyond 2080
- **Preparing the nuclear of the future: R&D on Gen 4 systems - SFR (Sodium Fast Reactor) chosen mainly because of its industrial maturity**
  - Uranium scarcity is the deployment criterion for Gen 4 systems, provided they are competitive
- **Waste management** : the assessment of transmutation options (2012) will have to encompass the potential benefits in long term high level waste management and the impacts on future fuel cycle facilities and reactor operation (safety, radioprotection, costs)

The Gravelines NPP
6 x 900 MW PWR units

eDF

EDF's point of view on Gen 4 SFRs

➧ EDF made a thorough feedback on FBR (PX and SPX) design, building and operation to derive requirements for the future Gen 4 SFRs

⇨EDF considers that strong improvements are to be brought in safety, availability, ISIR and construction costs

EDF's first utility requirements for the industrial Gen 4 SFRs

- **Safety level** equivalent to Gen 3 LWR's: similar safety objectives, robust demonstrations
- **Physical Protection**: equivalent to EPR
- **Uranium resource**: breeding capability requested
- **Waste**: assessment of the benefits and drawbacks of MA recycling, capability may be requested
- **Operational performances and investment protection**: to be dramatically improved: availability, ISI, repair, fuel handling, maintenance, materials selection, …
- **Capital cost** and operation costs : equivalent to Gen 3 at the time of deployment
- **Proliferation resistance** : reactors and fuel cycle facilities to be considered together. Increasing the complexity of the chemical processes is not an appropriate solution

Specification produced from:

- The GIF roadmap
- The Gen 3 utility requirement documents (EUR, EPRI-URD, …)
- The feedback of experience from the former French SFRs
- The French 3-party R&D works on Gen 4 SFRs

EDF's first utility requirements for the industrial Gen 4 SFRs

- Necessary progress with reference to Gen 3 and to the former French SFRs
- Distances to the EDF requirements are not uniform.
- Table: progress necessary along the GIF design goals

++ significant progress

+ some progress

= right level

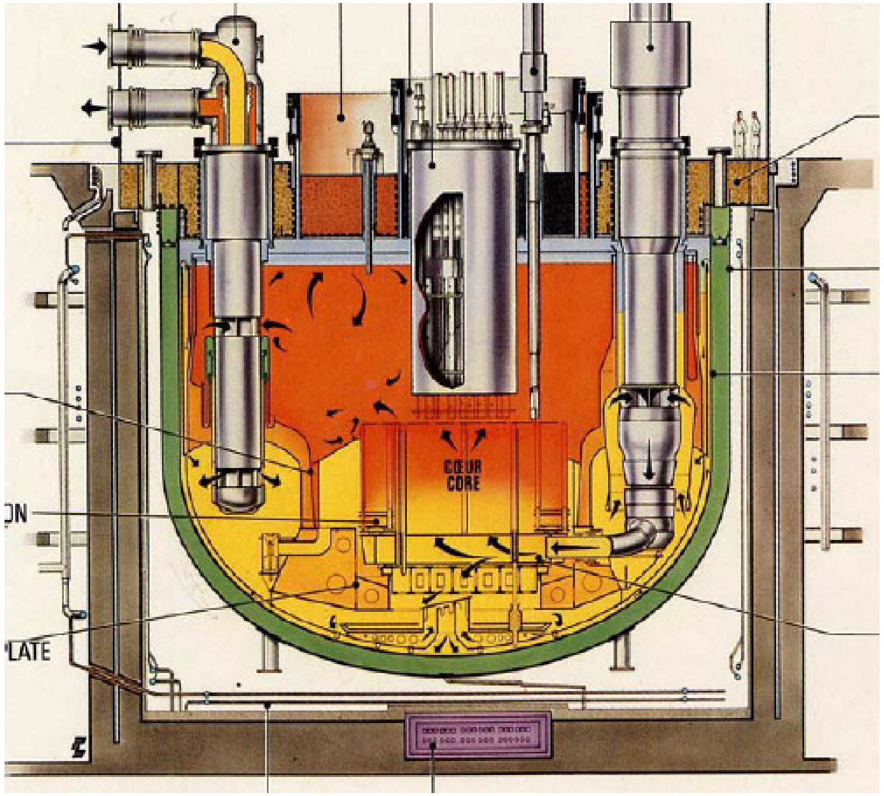
		Gen 3 LWRs	Former French SFRs
sustainability	Resource utilization	++	=
	Waste minimization	++	+
economics	Life cycle cost	+	++
	Risk to capital	+	++
safety and reliability	Operational safety and availability	=	++
	Core damage	=	+
	Off-site emergency	=/+	++
PR & PP	Proliferation resistance	≠	+
	Physical protection	=/+	++

Design goals listed as in GIF roadmap

EDF

EDF's R&D program for the industrial Gen 4 SFRs

- R&D on Gen 4 systems: ~ 5% of EDF nuclear R&D budget
- Around 30 engineers on SFR program
- EDF plays the role of a utility, not of a designer nor of a vendor nor of a government R&D agency
- Five projects:
  - **Fast reactor and system studies**
  - **Materials**
  - **Deployment strategies and scenarios**
  - **Fuel Cycle**
  - **Operation feedback analysis and utility requirements**
- EDF party of the trilateral French SFR program in partnership with CEA and Areva
- A collaboration agreement between EDF and JAEA



the Superphenix reactor

The French SFR Prototype and the R&D program (1/2)

- A fast reactor prototype is foreseen in the French 2006 law
- This prototype is scheduled to start operation in the 2020's time frame
- What should be its role ?
  - A research reactor? (for concept validations or transmutation physics for instance)
  - A demonstration reactor with industrial capabilities, at a smaller scale?

French law dated June 28 2006 about nuclear materials and waste management

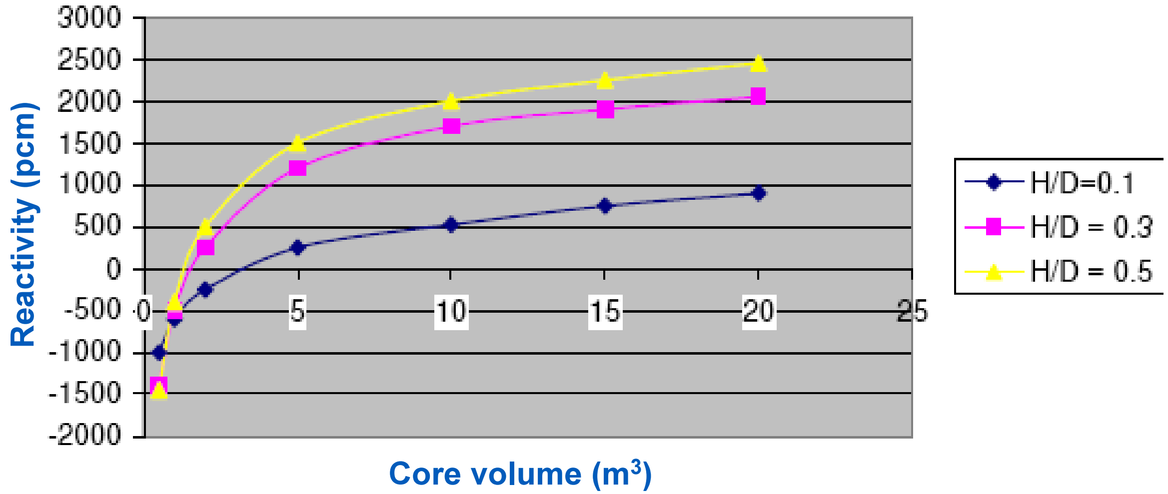
The French SFR Prototype and the R&D program (2/2)

- **What's an « industrial » prototype for EDF?**
  - It fulfils the specifications of the industrial reactor but at a smaller scale. It has the capability for extrapolation in all the domains
    - Core physics, safety methodology, severe accidents, technology, main components, safety approach, general layout, operation, maintenance, ISI, repair, proliferation resistance, cost, fuel cycle facilities, ...
  - Significant progress needed compared to the 1980's -1990's state of the art (SPX, EFR)
  - It is designed and built by industry
  - After the prototype, a FOAK can be directly engaged

French law dated June 28 2006 about nuclear materials and waste management

A few utility requirements for the French SFR prototype as seen by EDF

- Core physics and safety : the safety approach of the prototype should be as similar as possible to the safety approach of the commercial plant
  - This excludes using a too small core to get more favorable safety parameters. The sodium void effect of the prototype core must be of the same magnitude as the one of the commercial reactor
  - This requirement sets a lower limit to the prototype core volume (~5 m^3).



Sodium void effect as a function of volume

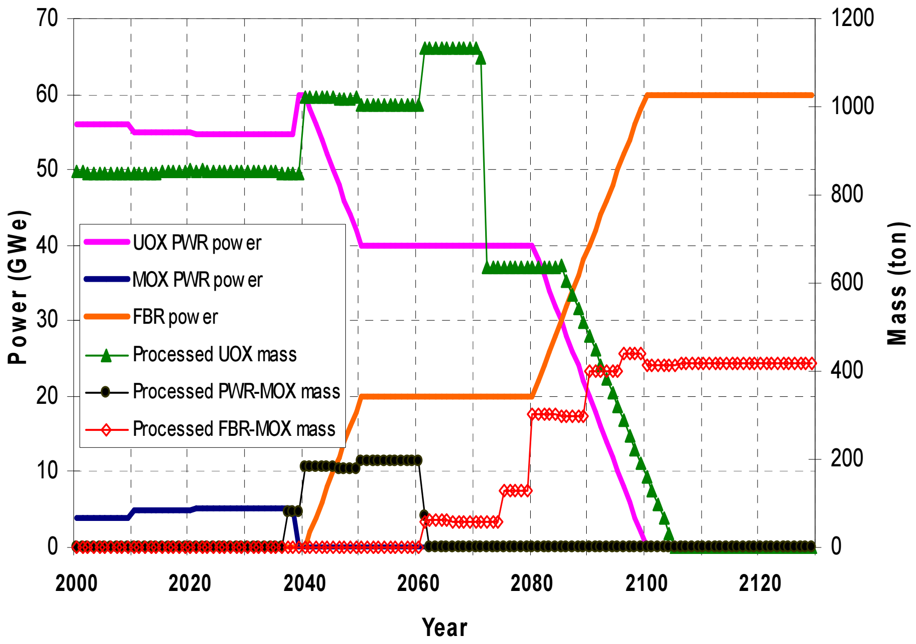
From Zaetta & al CEA

A few utility requirements for the French SFR prototype as seen by EDF

- Core physics and safety : the safety approach of the prototype should be as similar as possible to the safety approach of the commercial plant
  - This excludes using a too small core to get more favorable safety parameters. The sodium void effect of the prototype core must be of the same magnitude as the one of the commercial reactor
- Other Safety Requirements include
  - Sodium Fires and violent water sodium reactions
  - External Hazards and physical protection
  - Safety Methodology for the pre conceptual design phase 2009-2012 (includes dialogue with the regulator)
- Operations and availability requirement : to be dramatically improved with respect to the Superphenix level. The prototype will have to reach an availability factor k_d = 80% or more
  - Outages for special handling programmed in advance on the prototype are excluded from this factor as well as other operations pertaining to the nature of prototype
- In Service Inspection Requirement : the prototype should be designed to demonstrate the effective capability of the inspection of a major supporting structure inside the reactor vessel (and other inspections of the same type)
- Others : Plant lay out, fuel handling, components fabrication, Energy Conversion System

Fuel cycle scenarios : EDF's point of view

- A two stage deployment scenario for FBR has been simulated (see figure)
- « Minor actinides recycling » scenarios are also studied in the framework of the French 2006 waste law
- A geological repository opened under the conditions of the law in 2025 for HLW
- A recycling of MA in heterogeneous blankets may then be adopted if feasible and if technological and economic benefits outweigh possible drawbacks
  - Impact on the repository area (heat load)
  - Impact on surface facilities through the entire fuel cycle (heat load and associated activity)
  - Safety will always remain the ultimate judge in all the facilities above and underground
  - A very big amount of research is integrated in the elaboration of glass canisters. No such amount of research is available for technical criteria of MA surface facilities



In this scenario, the total electric power remains constant (60 GWe) over the 21st century: PWRs decommissioned between 2040 and 2080 are replaced with FBRs

Conclusions and perspectives

- Very significant improvements are needed for Gen 4 SFR, in comparison to PX-SPX-EFR
- Work is well in course in the frame of a tripartite collaboration
- EDF is defining more completely and precisely its requirements for the 2040+ commercial reactor and the level of verification brought by an « industrial » prototype
- These requirements will be used to check whether R&D results and the prototype conceptual design answer to EDF's needs
- A key milestone is 2012 as presented by Mr. P. Franck CHEVET (French Directorate for Energy and Climate Change) at the Global 2009 Conference: the reports will be presented to the French Government and Parliament
  - A milestone for the french radioactive waste management policy
  - As for the SFR prototype, the report will have to address four issues : safety, fuel cycle and P/T, costs, industrial needs

Thank you for your attention

CHANGER L'ÉNERGIE ENSEMBLE

The prototype in the French 2006 law

Bill of June 28, 2006 on a long-lasting sustainable management of radioactive materials and waste:

Section 3.1: « *Research on Partitioning and Transmutation is conducted in relation with that on* ***new generations of nuclear reactors*** *mentioned in the Energy Policy Bill of July 13, 2005, as well as on* ***accelerator driven systems*** *dedicated to the transmutation of waste, so as* ***to have in 2012 an assessment of the industrial prospects of these reactor types*** *and* ***to put a prototype into operation by the end of 2020*** ».