Sustainable Nuclear production in France

EDF Nuclear Fuel Cycle

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Sustainable Nuclear Production in France

Nuclear production : Safety as main priority

58 PWRs with standardized series 900 MW (34), 1300 MW (20) and 1500 MW (4)

→ **418 TWh in 2008, availability 80% ,** ≈ 77 % of electricity generation in France

→ launching of the new EPR reactor at Flamanville 3 (to be commissioned in 2012)

Perspective for the future :

- long term operation of existing NPPs and studies beyond 40 years
  periodic safety reassessment process, experience feedback, backfitting ....

- preparation for EPR deployment : timeframe 2020 to 2030…

- International development based on EPR standardisation: UK, USA, China, Italy…

- participation to GEN 4 advanced fast reactors programs, timeframe 2040 + …

Reactor core and fuel management

The current fuel management

- average burn up 44 GWd/t , average enrichment 4%

- 900 MW CP0 (6 units): 4.2% per third and 18 months cycle on CP0 units (6 units);

- 900 MW CPY (28 units): 3.7% per quarter and 13 months cycle on CPY units with 22 units loaded with MOX fuel and 2 units loaded with REPU fuel;

- 1300 MW units (20 units): 4% per third and 15/18 months cycle;

- 1500 MW N4 units (4 units): 4% per third, 17 months cycle.

Fuel management policies

- Implementation of MOX Parity fuel management and extension on 900 MW plants (22 units authorized as of today), MOX equivalent to UO2 3,7% (52 GWd/t, 8,5% Pu)

- Adaptations as needed to ensure recycling and fuel cycle consistency (evolution of burn up..)

- Security of supply and Diversification

The choice for reprocessing and recycling strategy

- **Reprocessing of spent fuel has been implemented in France from the beginning**
  - initially: to enhance energy independence, along with fast breeder reactors program
  - current status: transportation and reprocessing of spent fuel at the La Hague facility;

- **Spent fuel represents a valuable energy resource**

  (1%) plutonium as long term energy resource, under safeguard rules

  (35% of fission energy in situ in UO2 fuel + possible 10% with recycling)

  (95%) recovered uranium, still sligthly enriched (0,8% U235)

  (4%) fission products and minor actinides (Am, Cm, Np) to be treated as waste and vitrified.

- **High level waste vitrification and recycling of valuable energetical material remain the main options for the back end of the fuel cycle**

→ the vitrification process is a major factor for long terme safe confinement of high level waste, interim storage and disposal under reduced volume

→ decision to recycle plutonium in PWR 900 MW, using a mixed uranium / plutonium fuel (MOX) first MOX loading in 1987 at Saint Laurent B, extended now to 22 units PWR 900 MW

→ use of REPU fuel on two 900MW units (extension to 4 units)

→ preservation of long term energy resource (use of plutonium for future fast reactors)

Nuclear fuel cycle industry in France
A major contribution to energy sustainability

Uranium and conversion
≈ 8000 t/year

Enrichment
≈ 5,5 MUTS/year

UO2 Fuel fabrication ≈ 1060 t/year
2000 assemblies/yr (45 GWd/t average, max 52 GWd/t

→ *time period*
20 years

430 TWh /an

58 EDF NPPs
22 units loaded with MOX
2 with REPU

Spent Fuel:
1200 tons /year
(UOX et MOX)

Recycling: MOX fuel
100 t/year on 22
units 900 MW (30% core) --> 40 TWh/yr

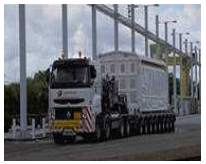
MELOX
Fuel
Fabrication
plant

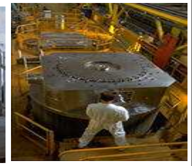
8,5 t /yr
Separated
plutonium (1%)

Reprocessing :
850 t / year

La Hague

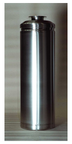
Spent Fuel
Transportation to
La Hague,
interim storage
in cooling pools
1200 tons/year





Reprocessed uranium: ~ 810 t/yr
(U235 content 0,8%)
1/3 re-enriched and recycled
on 2 units 900W (100% core)
or 40 t/yr --> 15 TWh/yr
to be extended to 4 units

Vitrified High level Waste
Interim passive storage
Disposal optimisation



110 to 130 m³/yr vitrified HLW

122 m³/yr compacted ILW

A closed Nuclear Fuel cycle: a sustainable policy

- UO2: ≈ 1100 t/yr, max 52 GWd/t (45 GWd/t average), study up to 58/60 GWd/t (with enrichment 4,5%)

- reprocessing of spent fuel at La Hague:
  → vitrification of High Level Waste
  → in line with MOX recycling possibilities, no Pu stockpile (technical buffer)

- MOX fuel recycling:
  ≈ new authorization up to 52 GWd/t (8,65% Pu, equ UO2 3,7%),
  2 more units loaded with MOX ==> 22 units (30% of core)
  10% of nuclear production (42 TWh)

- Establishment of a commercial agreement between EDF and Areva covering long term recycling of spent fuel:
  with a perspective for a gradual increase of the MOX fuel quantity to be recycled (up to 120 t/yr)
  and an increase of the spent fuel quantity to be reprocessed (up to 1050 t/yr), as from 2010 to 2012.

- REPU recycling: 2 units (100% core), extension to 4 units at Cruas

- storage of vitrified HLW at La Hague: 1 ha for 40 years of EDF nuclear fleet production, > 60 years

- preparation for future disposal for HLW: laboratory at Bure (East of France - clay layer 500 m deep),
  license application for 2015, commissioning for 2025

Nuclear fuel cycle industry in France
A major contribution to energy sustainability

The current reprocessing recycling strategy is a major asset for sustainable nuclear energy in the following respects:

- **Ensuring a safe and long lasting confinement of high level waste by vitrification in inert glass canisters under a reduced volume**,
  a safe and long-lasting containment, internationally recognized
  in a suitable form to be stored and ultimately disposed of in an optimised package,
  under limited volume (130 m3/year for 400 TWh) and disposal cost;

- **Reducing the quantity of stored spent fuel,**
  7 UO2 spent fuel result in 1 MOX spent fuel, in which plutonium is concentrated (5%);

- **Recycling of plutonium and recovered uranium, while getting back energy output**
  produces 30 to 40 TWh/yr (8 to 10% of nuclear production) in 20 units (30% of the core)
  2 units feeded with REPU fuel (100% core), to be extended to 4 units

- **Maintaining the possibility in the far future to use the plutonium resource**
  concentrated in MOX spent fuel, under small volume, full safeguards
  leaves open the possibility to reuse Pu in future GEN4 fast reactors

Nuclear fuel cycle industry in France
A major contribution to energy sustainability

- This strategy is robust and flexible in term of flow sheet and volume of nuclear materials (spent fuel, plutonium, REPU…).

- It gives time and can be extended for the years to come, while preparing for future options.

- It results in a safe and optimised high level waste interim storage and disposal (limited volume), along with nuclear energy resource preservation.

- It relies on existing industrial tool, to be amortised in the long run.

Studies for future back end options: the June 2006 law on Sustainable management of Radioactive Material and Waste

1/ R&D studies to be pursued on three complementary lines:

- Partitioning and transmutation of HLW, in relation with studies on future reactors, to assess the industrial perspectives for those systems (2012) and to develop a prototype reactor (2020);

- Geological disposal, as a reference solution, in order to prepare a licensing procedure (site selection, design options..) in 2015 and implementation in 2025;

- Interim storage: new capacities, or existing to be adapted, for 2015, according to the needs;

2/ A National Program for the Management of Nuclear Material and Radioactive Waste, featuring reduction of the quantity and toxicity of radioactive waste, notably through spent fuel reprocessing and treatment of radioactive waste;

3/ Financial settlements

- for local economic development and R&D expenses (Andra),
- for cost assessment for HLW management options and related provisions (long term liabilities) with dedicated financial assets.

Conclusion

- The on going challenges
  - first priority: nuclear safety
  - acceptability issue: waste management
  - best use of energy resource

- The reprocessing recycling strategy brings a robust answer to high level waste management and allows to use fissile material rationally, while benefiting from existing industrial tool in the long run, which contributes to nuclear economics.

- A perspective open to future progress and optimisation, as needed to meet long term energy sustainability.