# FRENCH NATIONAL REPORT

## 1. FRENCH ENERGY POLICY AND LEGAL FRAMEWORK FOR WASTE MANAGEMENT

### *The French Energy Policy*

In France the development of an ambitious nuclear power program associated with a closed fuel cycle was driven by the political will to achieve a substantial level of energy independence in a country poorly endowed in fossil fuels and having domestic uranium resources available in limited amount. The energy independence goal assigned to nuclear power has been achieved. Since the beginning of the nineties, nuclear power has been fulfilling about three-quarters of the electricity demand in France, a sizeable contribution to the decrease in energy imports (decrease of € 16 billion in 2006). A key added benefit is the avoided emission of CO2 (about 126 Mt in 2006).

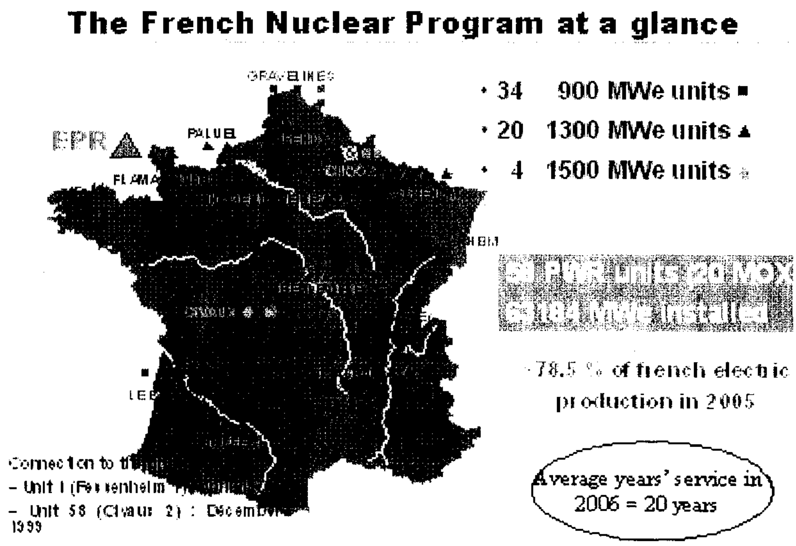
According to the 2005 law establishing guidelines for France energy policy and security, the government makes sure that Nuclear Power provides an important share of the electricity mix. To maintain the nuclear option open after 2020, a new generation reactor must be available by 2015 on a commercial basis. In the framework of this 2005 global energy act, a research policy is also defined to sustain the development of innovative energy technologies consistently with the French climate plan aiming at reducing the emission of greenhouse gases. This roadmap includes several key steps such as: implementation and testing of a first of a kind GENERATION III (EPR) reactor so as to be able to decide for a series by 2015, R&D on future nuclear systems (GENERATION IV fission reactors, fusion reactors), new energy technologies (including hydrogen economy, innovative fuels for transport sector) and energy efficiency.

The contribution of nuclear power to the French energy policy was further reinforced with the following major initiatives :

- In January 2006, President Chirac announced the construction by the CEA of a Generation IV prototype reactor to be completed in 2020.
- Establishment of an independent safety authority (its mission was defined in a new law on nuclear transparency and security enacted by the French parliament on June 13, 2006).
- In June 2006, a new act on "*the sustainable management of radioactive materials and waste* "was approved by the French Parliament. The act includes provision for a national plan (PNG-MDR) on radioactive materials and radioactive waste management updated on a regular basis to further define and update the R&D goals and milestones for GENERATION IV systems (see next chapter).

### *The French nuclear power fleet: status and prospects*

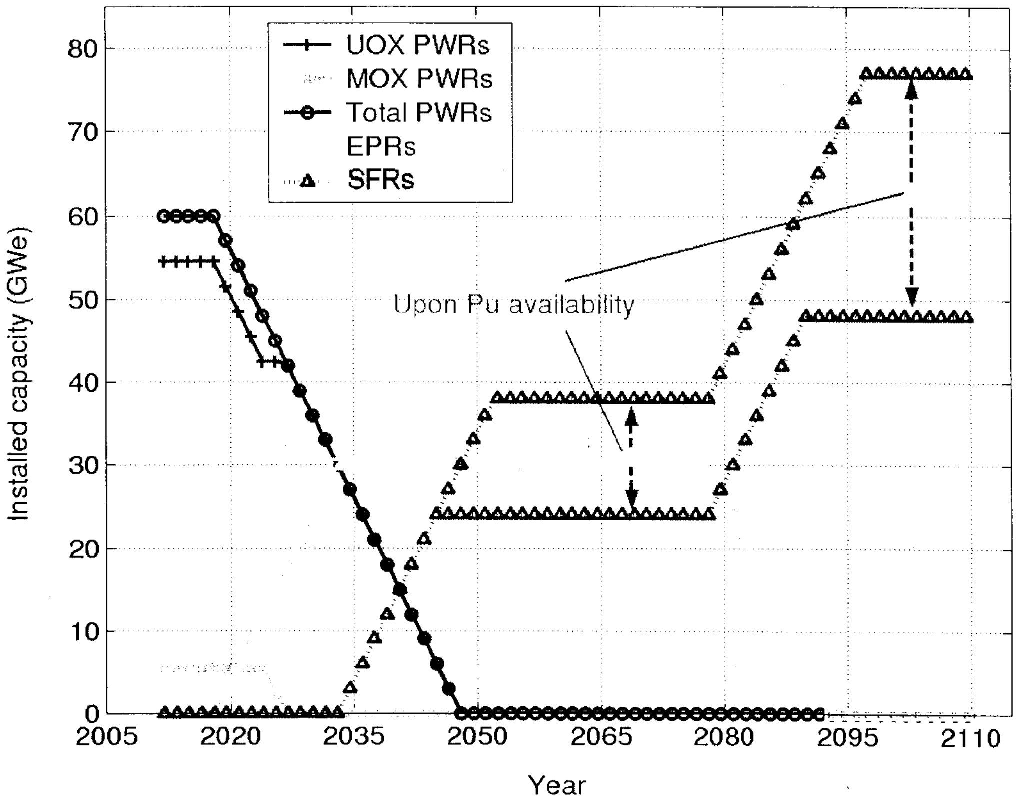
The operating French nuclear reactor park comprises 58 PWR units owned and operated by EDF (Electricité de France). The FNR Phénix is jointly owned by CEA (Commissariat à l'Energie Atomique) and EDF. The 63.5 GW(e) installed nuclear capacity allowed the generation in 2006 of approximately 430 TWh net, contributing to more than three quarters of the total electricity produced in France.




The construction of an EPR, a new reactor type, is being started at Flamanville for operation in 2012. This 1600 MWe EPR type reactor and the Finnish EPR at Olkiluoto are the two first units of a standardised new family of GENERATION III reactors, designed by AREVA NP for 60 years operation. This standardised GENERATION III reactor is designed as a highly competitive tool for electricity production. A decision for a large scale industrial deployment (series) is expected from the French utility by 2015.

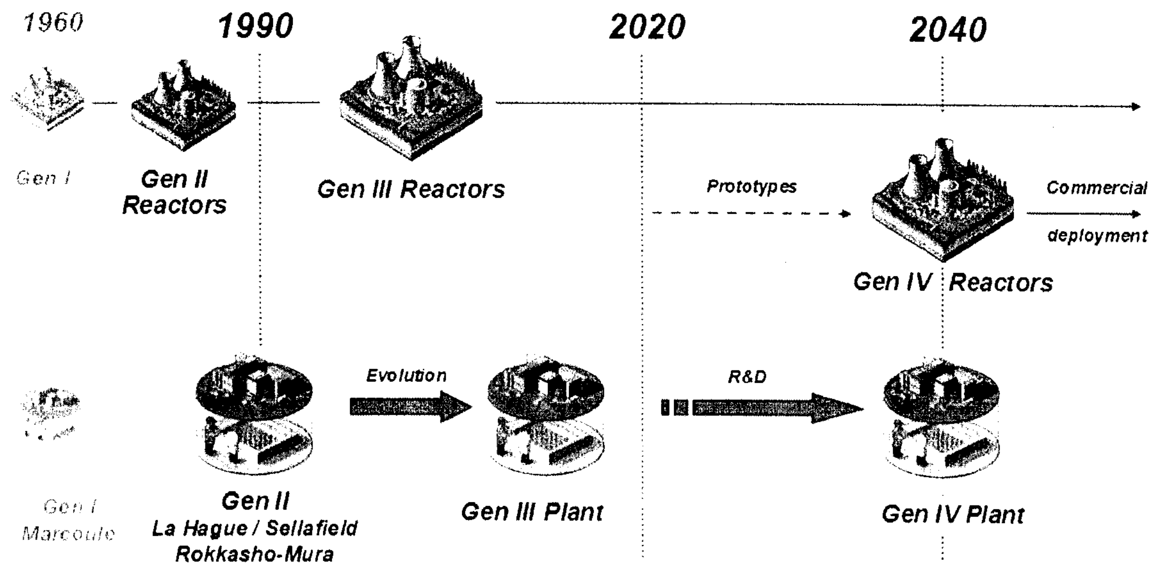
The first GENERATION IV prototype is to be built by 2020. Industrial implementation is expected by 2040.

The following figure presents EDF vision on progressive implantation of GEN III and GEN IV reactors, according to its scenarios on future electricity demand as well as needs for older reactors replacement.




The fleet renewal scenario is based on 2 GWe/year new power capacity to be built starting from 2020.

The relationship between nuclear reactors successive generations and treatment plants evolution is illustrated below.




- Integrated Treatment-Recycling plant
- Co-extraction and co-management of Uranium and Plutonium (COEX™ process)
- In-line fabrication of LWR MOX fuel [U + Pu]
- Evolutive design to integrate over time new processes

### *Overview of the back-end developments in France*

About 1100 t of irradiated fuel are unloaded every year and transported to the AREVA NC La Hague Facility for treatment.

AREVA has the capacity to reprocess up to 1700 tHM/year of irradiated fuel in its La Hague facility and to market 195 t/year of MOX fuel for French and foreign customers. At La Hague, two reprocessing plants are operational: UP2 dedicated to treat French PWR fuels and UP3 initially dedicated by contract to treat foreign fuels (essentially Belgian, Dutch, German, Japanese, Swiss). French origin irradiated fuels are now also treated in UP3. All MOX fuels are now fabricated at the AREVA NC Melox plant in Marcoule. The AREVA NC Cadarache plant ceased MOX production in 2004.

The back-end strategy and industrial developments are to evolve progressively according to future needs :

- French NPP evolution, i.e.: changes in the fuel management strategy for operating PWRs, step by step implementation of EPR units, manufacturing of driver fuel for the GENERATION IV prototype, manufacturing of minor actinides bearing fuels to be tested in this demo plant, industrial implementation by 2040 of GENERATION IV fast systems. The associated fuel cycle technology is to be selected accordingly on an evolutionary design basis so as to be adaptable to the various possible recycling strategies and emerging needs of the market place. In this respect, three main R&D lines are kept open (see Chapter 3) for the next decade :
    - No pure plutonium separation process based on co-extraction/co-conversion of uranium and plutonium (COEX™) – and possibly neptunium – as designed for GENERATION III reprocessing plants and which are close to near term industrial deployment.
    - Selective separation of long lived radionuclides from raffinate (with a focus on Am and Cm separation) based on the optimization of DIAMEX-SANEX processes for their recycling in heterogeneous mode in GENERATION IV systems. This option can also be implemented with a combination of COEX™ and DIAMEX-SANEX processes.
    - Group extraction of actinides (through GANEX processes) as a long term and challenging R&D goal for a homogeneous recycling of actinides in GENERATION IV fast systems.
- New market needs : reprocessing of foreign irradiated fuels, IAEA multinational approach of the fuel cycle (e.g. through regional centres), plant with high efficiency, adaptable to MOX reprocessing both for PWRs and Fast Reactors, integrated fuel treatment-refabrication facility with no pure plutonium separation, manufacturing of high performance MOX fuels.

### *The legal framework for nuclear waste management*

The Waste Management Act of 1991 defined the legal framework for managing HLW. It organized the R&D along axis:

- Separation and transmutation (with CEA and CNRS as main contributors);
- Disposal in deep geological layers (R&D led by ANDRA);
- Long-term (sub)-surface storage (R&D led by CEA).

A status report assessing the most promising R&D routes was submitted to French authorities in 2005.

As a result, the legal framework for the waste management in France was updated with two important laws, both enacted in 2006:

— The Law on nuclear transparency and security established a new independent safety authority ASN (Autorité de Sûreté Nucléaire). The ASN is chaired by a college of 5 members appointed for 6 years. It ensures the control of nuclear safety and radiation protection to protect workers, patients, the public and the environment from risks related to the use of nuclear technology.

— The Programme Act on the sustainable management of radioactive materials and wastes is about all types of radioactive waste (not only long lived high level waste). It defines three main principles concerning radioactive waste and substances: reduction of quantity and toxicity, interim storage of radioactive substances and ultimate waste, deep geological disposal. The law retains retrievable deep geological storage as the reference solution for long lived and high level waste. The French parliament will be consulted again by 2015 on possible designs of the disposal site. A national disposal centre might be operated by 2025 subject to Parliament authorization. The disposal in France of foreign irradiated fuel or radioactive waste is prohibited. The law defines financial arrangements for research, nuclear plants decommissioning charges, additional taxes on nuclear facilities to finance research programs. It provides also clear definitions for radioactive materials and waste and specifies that treatment is the way to reduce the volume and radiotoxicity of nuclear waste. A central point is the creation of a national management plan defining the solutions, the goals to achieve and the research actions to be launched to reach these goals. This plan is updated every three year and published (according to the law on nuclear transparency and security). The law insists on transparency and democratic control.

### *The waste disposal managed by ANDRA*

Nuclear facilities are conditioning all waste according to safety authority requirements. Those originating from France can then be transferred to ANDRA for disposal, according to their specifications, in several dedicated sites. Conditioned high level and long lived wastes are stored at production sites pending the creation of a disposal site by ANDRA.

ANDRA is currently operating the Soulaines disposal facility for Low and Intermediate Level Waste and the Morvilliers disposal facility for Very Low Level Waste. In 1999, ANDRA was authorized to build in the Bure area an underground research laboratory for long lived HLW and ILW disposal.

## 2. BACK END OF THE FUEL CYCLE IN FRANCE

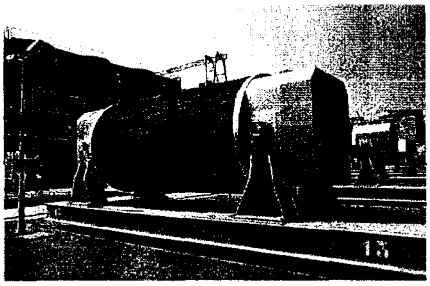
In France the closed fuel cycle increases the nuclear power program's sustainability as it allows the recovery of fissile materials to fuel present and future generation reactors. It furthermore provides a safe and secure management of wastes while significantly minimizing the burden left to future generations.

## 2.1 *PRESENT STATUS*

### 2.1.1 IRRADIATED FUEL TRANSPORTATION AND INTERIM STORAGE

Approximately 1100 t of irradiated fuel are unloaded every year from the French reactors. After a few years of cooling down in pools at the reactor sites, irradiated fuel is shipped to the AREVA NC La Hague Facility where it is stored in pools for an additional cooling period before being reprocessed. The cumulated authorized pool capacity at the La Hague plant is about 18,000 tHM.

Transports of French and foreign irradiated fuel to the La Hague plant are carried out by TN international, an AREVA NC subsidiary. The company has acquired a large international experience in metal casks and concrete casks for transport and/or storage of irradiated fuel.



Irradiated Fuel Transportation cask

Irradiated Fuel Storage at La Hague Plant

### 2.1.2. REPROCESSING

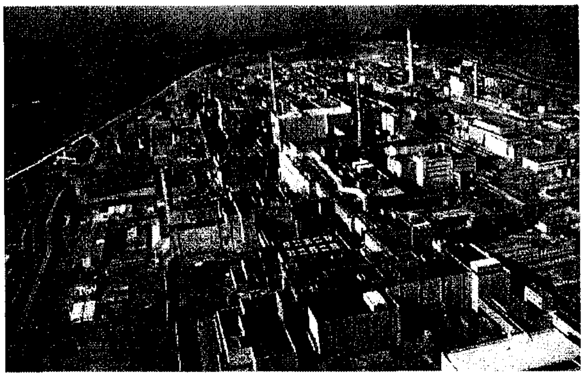
In France, GCRs (Natural Uranium Graphite Gas Reactors), FBR's, PWR's and RTR's (Research and Test Reactors) were or are in operation. The irradiated fuel coming from these different types of reactors have all been reprocessed in the past 40 years in 3 reprocessing plants: UP1, UP2 and UP3. The experience gained by the French industry has benefited other countries. By the end of 2006, more than 18,000 tHM of GCR fuel and approximately 22,700 tHM of LWR fuel coming from France and other countries had been reprocessed.

**UP1 (Marcoule)**

The UP1 reprocessing plant (PUREX process) located in Marcoule (Rhone Valley), started civilian operations in 1965 with the reprocessing of irradiated nuclear fuel from French and foreign GCR reactors. In 1978 the first French vitrification facility (AVM) was added to the UP1 plant to condition HLW waste.

By 1997 end, GCR reprocessing had ended in UP1 and the plant was shut down in 1998. An Economic Interest Group for the management of all the decommissioning operations was set up by CEA, AREVA NC and EDF. The closing down phase including advanced rinsing and removal of nuclear material was completed in 2002 and total dismantling funded mainly by EDF and CEA should be accomplished within circa 30 years.

# AREVA NC La Hague (UP2 – UP3 plants)



*The AREVA NC La Hague Reprocessing site*

In 1966, a second reprocessing plant referred to as UP2-400 was commissioned in France, at the La Hague site (in Normandy). With a 400 tHM/year initial capacity, this plant was operated to reprocess GCR fuel. In 1976 a new head-end (High Activity Oxyde, HAO) was added to UP2 in order to reprocess LWR fuel. In 1994, UP2-400 was upgraded to meet the French growing reprocessing needs and renamed UP2 800.

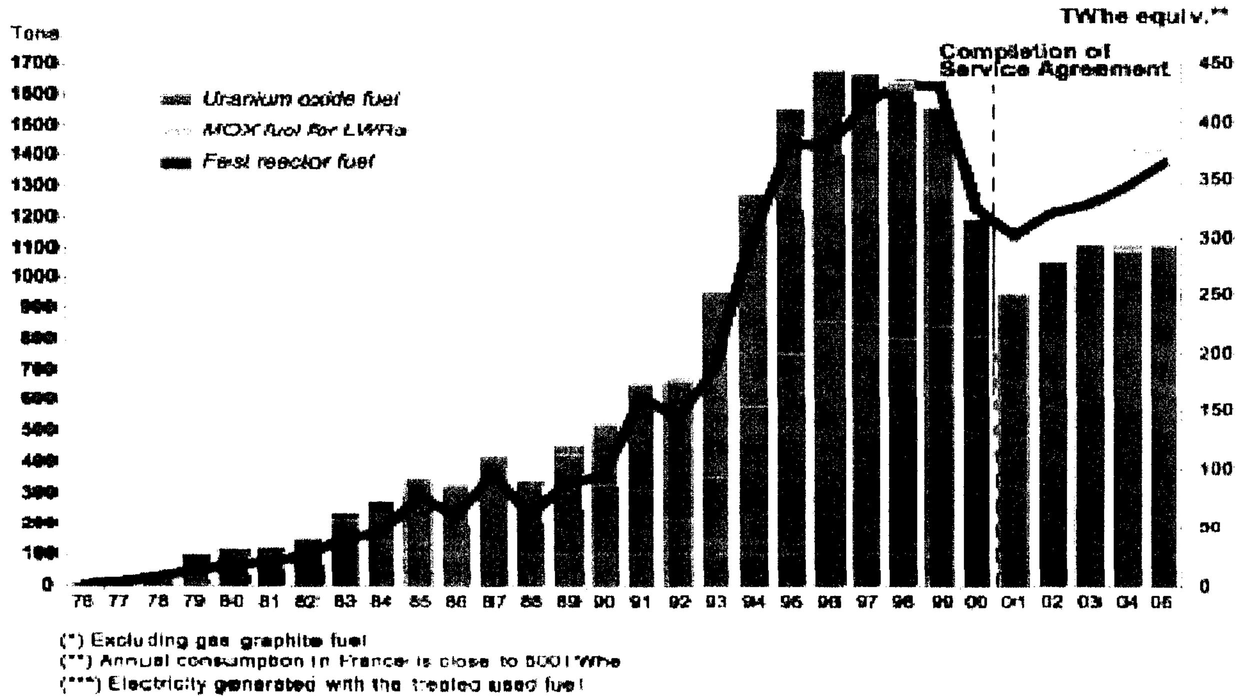
In 1989, an additional plant named UP3 was commissioned to reprocess foreign origin irradiated fuel.

The two presently operating La Hague plants are based on the PUREX process.

Following a public inquiry in May 2000, AREVA NC was authorised in three decrees dated January 10, 2003, to modify the operating conditions of UP2 800 and UP3. The individual capacity of each of the two plants was raised to 1000 t per year of heavy metal (U or Pu), with the total capacity of the two plants being limited to 1700 t.

**La Hague historical production data**

About 22,700 tHM had been treated at AREVA NC La Hague by 2006 end (close to 12,700 tHM originating from France and more than 10,000 tHM of foreign irradiated fuel).



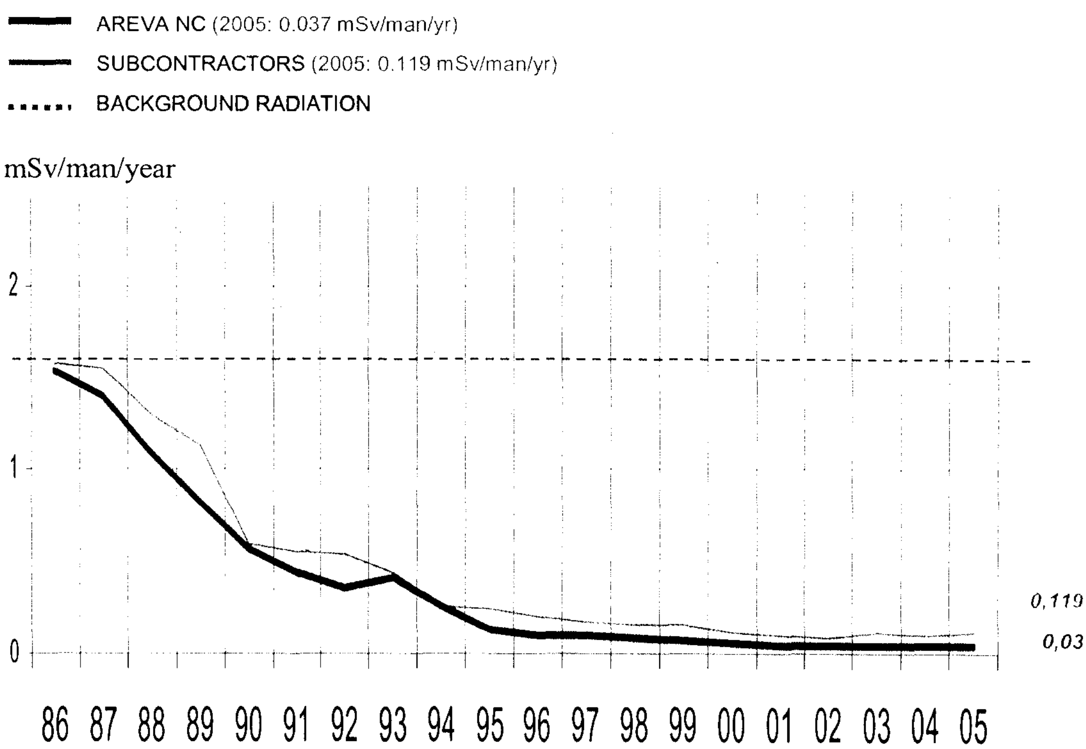
The next table details the status of irradiated fuels and materials received at La Hague by country of origin. Only 4% of the irradiated fuels and materials in pools by 2005 end are of foreign origin.

| | Metric tons at 12/31/2005 | Date of receipt by fuel type | MT already treated |
|---|---|---|---|
| France | 7 562 | 1985-2005<br>[illegible]<br>1997-2005 | 11,670 |
| Germany | 107 | 1992-2005<br>[illegible] | 5,310 |
| Belgium | 0.4 | 1998-2004 | 670 |
| Swiss | 103 | 1998-2005<br>[illegible] | 660 |
| Netherlands | 8 | 1994-2005 | 320 |
| Japan | – | | 2,940 |
| Australia | 0.2 | 2000-2003 | |

Uranium oxide fuel
MOX fuel (LWR)
MTR fuel

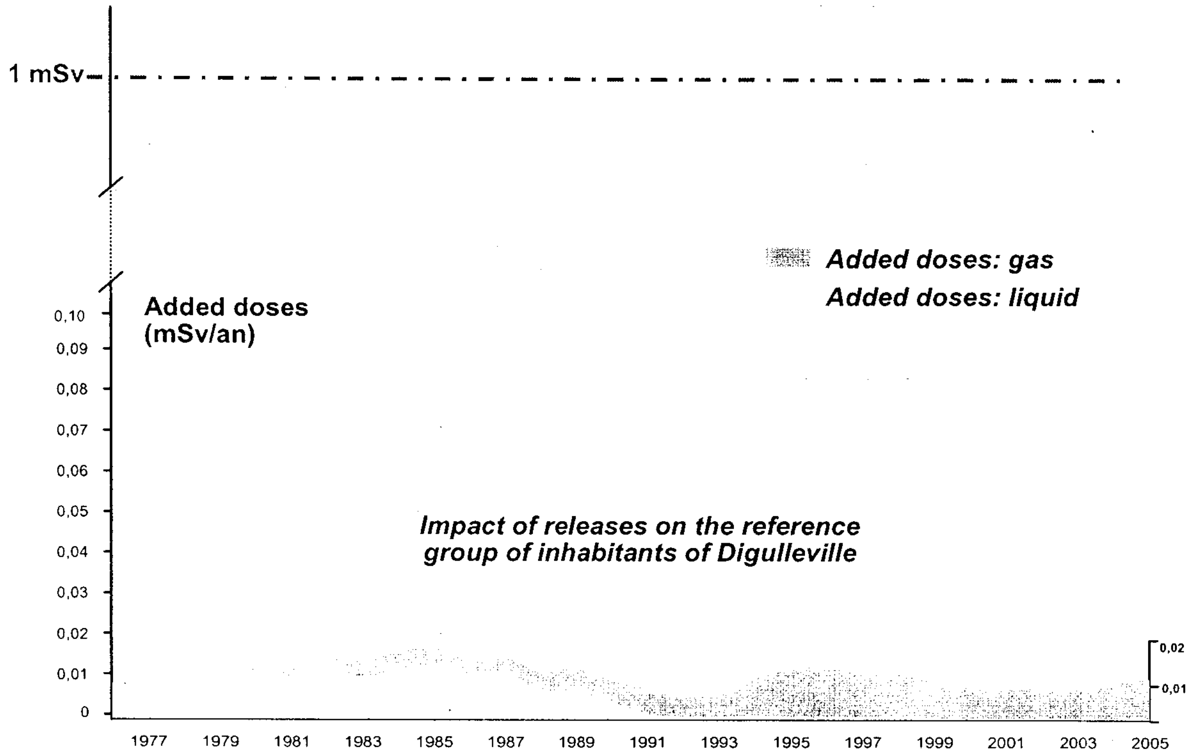
## La Hague occupational exposure

For the last twenty years La Hague average occupational exposure has remained below natural background. Its 2005 level was 0.073 msV/per employee. As a matter of comparison, the European Union limit is 20 msV per employee per year.



**La Hague impact on the local population**

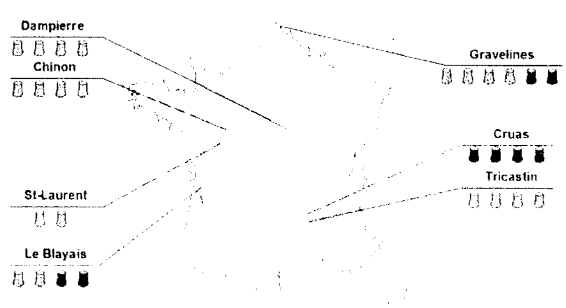
The added dose on the most exposed population has been averaging about 0.01 msV per person per year for the last twenty years. As a matter of comparison, the European Union limit is 1 msV per person per year.




2.1.3. RECYCLING

Plutonium recycling

EDF recycles PWRs plutonium from the reprocessing of its irradiated fuel in 20 of its 900 MWe.




**Reactors loaded with MOX (in orange)**
St-Laurent : B1 (1987), B2 (1988)
Dampierre : 1 (1990), 2 (1993), 3 & 4 (1998)
Le Blayais : 2 (1994), 1 (1997)
Tricastin : 2 & 3 (1996), 1 & 4 (1997)
Gravelines : B3 & B4 (1989), B1(1997), B2 (1998)
Chinon : B4 (1998), B3 & B2 (1999), B1 (2000)

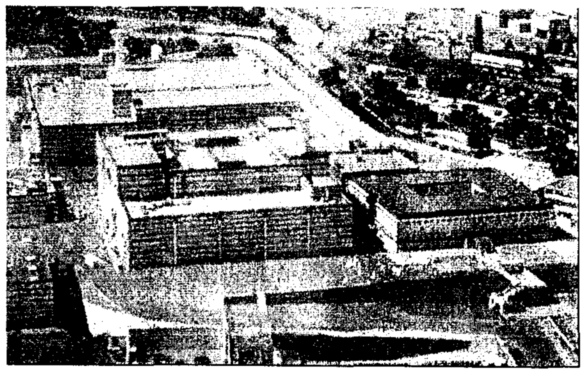
**Reactors technically capable for moxification (in blue)**
Gravelines C5 & C6
Blayais 3 & 4
Cruas 1 & 4

As of December 31st 2006, more than 2700 MOX fuel assemblies had been delivered to EDF. MOX fuel loaded in French PWR's is licensed for an average burn-up of about 40 GWd/tHM. In order to further enhance the availability and performance of reactors in operation, studies have been undertaken to further improve MOX fuel and its in core management. The objective is to implement the MOX parity management ensuring that MOX fuel delivers an energy equivalent to the UO2 fuel with a 3.7% enrichment in uranium 235.

The first plutonium recycling in France took place in the Rapsodie research reactor about forty years ago, the fuel being manufactured since 1961 at the Cadarache Plant located in the south-east of France. This plant then fabricated the MOX fuel for Phenix and Superphenix fast reactors. In 1987, the Cadarache plant was upgraded to produce MOX fuel assemblies for LWR. Its 40 tHM/y capacity was reached by the mid nineties. The AREVA NC Cadarache site ceased its commercial MOX production in July 2003 and is currently conditioning the waste from its former operations, before being dismantled.

All MOX fuel is now fabricated at the AREVA NC MELOX plant located in Marcoule (Gard region). This plant was commissioned in March 1995 reaching in 1997, its first nominal licensed capacity of 100 tHM/year. In September 2003, MELOX was authorized to increase its annual production level to 145 tHM. In September 2004, AREVA NC submitted a request to the French Competent Authorities to increase its production capacity from 145 to 195 HMt/year. License was granted in April 2007.

Over 1,100 tHM of MOX fuel had been fabricated by 2006 end.



View of the MELOX plant

<u>RepU recycling</u>

Reprocessed uranium (RepU) recycling has been demonstrated in two units at the Cruas NPP since the mid eighties. The RepU inventory being a strategic resource, its increased utilization is an option considered by EDF taking into account the evolution of the natural uranium market.

Reprocessed uranium is converted in COMURHEX plants at Pierrelatte, either to U3O8 for interim storage, or to UF6 for re-enrichment in centrifugation facilities. The enriched UF6 is then converted in the FBFC Romans plant (capacity 150 tHM/y) to UO2 fuel.

### 2.1.4 CONCLUSION

By 2006 end, about 22,700 tons had been processed at the AREVA NC La Hague plant and more than 1100 tHM of MOX fuel assemblies had been fabricated at AREVA NC MELOX Plant with minimum impact on public health and the environment:

— The occupational exposure at La Hague and MELOX is one or two orders of magnitude below the European Union limit of 20 mSv per employee per year.

— The radiological impact on the environment falls well under 1% of the European Union limit for the general public of 1 mSv per year.

— There had been no safety events at either of the two facilities above level 2 (incident) of the International Nuclear Event Scale which ranges from 0 (no safety significance) to 7 (major accident).

— An extensive third-party verified monitoring of the surrounding environment is permanent.

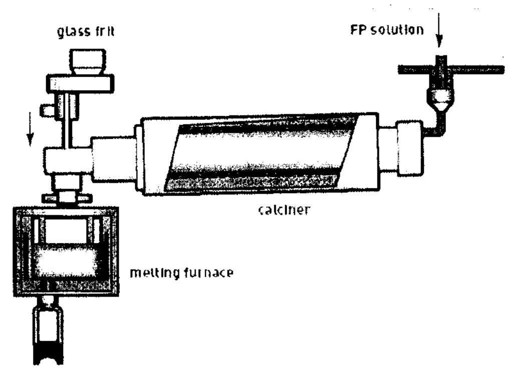
## 2.2. *IMPROVEMENTS AND PROSPECTS FOR INDUSTRIAL DEVELOPMENTS*

### 2.2.1 EXISTING PLANT IMPROVEMENT

UP2 and UP3 plant operations are based on the PUREX process. Their construction was decided in the seventies and massive production took place in the nineties, during which time plant operations were continuously improved. The uranium and plutonium separations factor has now reached 99.88%, leaving in the vitrified matrix only about one gram of plutonium for each kilo recovered, and contributing to the minimization of radiotoxicity and waste volume.

**Vitrification**

AREVA benefits from more than 20 years of industrial experience using hot crucible melter technology in three different vitrification facilities: AVM in Marcoule, R7 and T7 (respectively commissioned in 1989 and 1992) at the La Hague site. By the end of 2005, AREVA NC's vitrification facilities had produced over 15,000 canisters of vitrified HLW.




**Current two step Vitrification process:**

**About 22,700 tHM of irradiated fuel reprocessed in 'La Hague'**

**Pouring glass fabricated by the current two step process into a container**

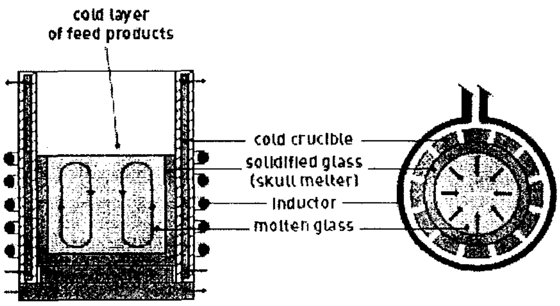
After fifteen years of operation in R7 and T7, each with a nominal capacity of more than 550 glass canisters per year, the life time of the melters exceeds design basis values by a factor of

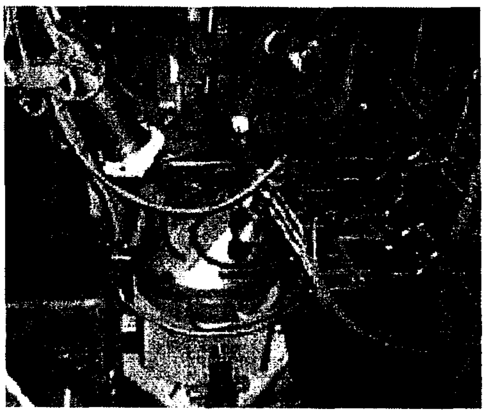
two. The feedback from active operation and R&D results has led to further improve the process in areas such as glass characteristics, associated technologies, operation and maintenance.

To broaden the performance range of the vitrification process, CEA and AREVA, with its engineering subsidiary SGN, have developed the use of the cold crucible melter (CCM) technology. It leads to a virtually unlimited equipment service life and allows a greater flexibility with respect to waste composition. The high specific power directly transferred to the melt by induction helps in adjusting glass temperatures.

### *Direct-induction cold crucible vitrification*

Direct-induction melting consists in placing the glass that is to be heated inside an alternating electromagnetic field, generated by an inductor. This field causes induced currents, which dissipate energy through joule effect inside the material resulting in its melting. With direct induction, the point is to heat the material to be melted, directly, without heating the crucible. The latter, on the contrary, is cooled by water circulation, and sectorized, to ensure relative transparency to the electromagnetic field.



Cold crucible developed for AREVA industrial application at La Hague.

Compared with the current process, the cold-crucible melting technology brings major benefits. First of all, cooling the melting furnace allows a thin layer of solidified glass to form, protecting the crucible and precluding corrosion from the molten glass. Second, heating by direct induction within the molten glass bath allows higher fabrication temperatures to be achieved, thus enabling design of novel, higher-performance waste-confinement matrices.

The technological test platform set up in 2001 by CEA and AREVA to demonstrate the feasibility of the advanced cold crucible technology (❶ – Cold crucible (diameter 1.1 m) , ❷ – Pouring glass station, ❸ – Gas treatment operation

To increase throughput and flexibility (with respect to liquid feed as well as solid feed acceptance criteria), the ACCM (advanced CCM) variant was developed. This design allows (in a single step process) to directly feed the melter with solid or liquid waste flow, while improving the glass throughput capacity.

**Hulls and end fittings compaction (ACC and ECC units)**

The compaction facility (ACC, Atelier de Compaction des Coques), which started operation in 2002, allows a four-fold reduction in waste volume resulting from fuel reprocessing. Structural parts of fuel elements (hulls and end-fittings) with long-lived radio-nuclides, which were conditioned in grout until 1995, are now compacted and packaged in universal canisters also used for vitrified waste. Each canister is filled with 5 to 7 discs according to their thickness, in order to produce less than 1.5 Universal Canister per ton of reprocessed irradiated fuel. Up to 2,400 canisters yearly can be produced at the ACC.

The Universal Canisters once produced in the compaction facility (ACC) are sent to an interim storage facility (ECC, Entreposage des Coques Compactées) before final shipment to the customer's designated facility.

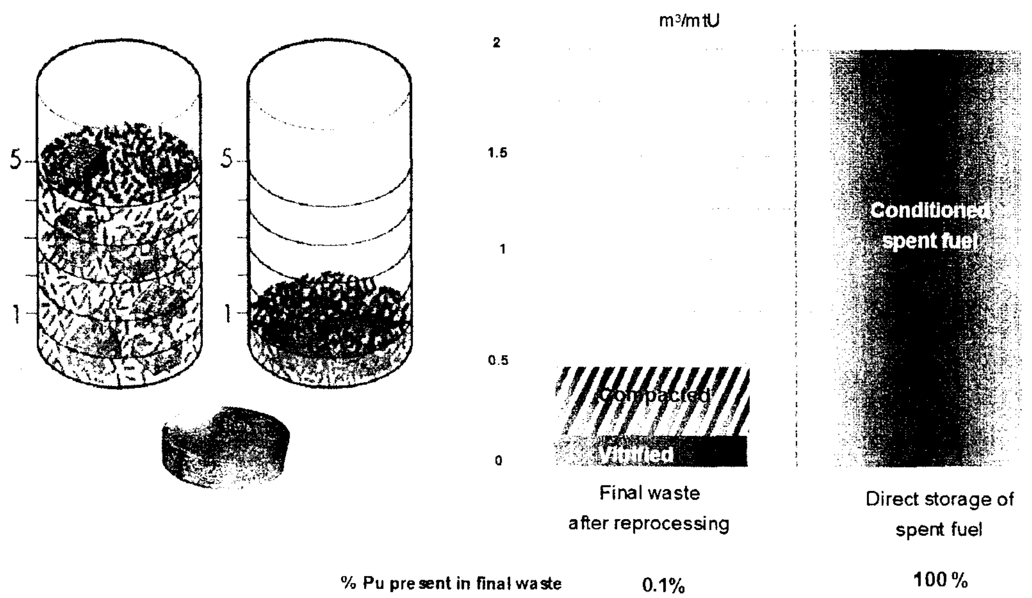
**New Effluent Management**

Thanks to the extraction process performance levels, the volume of low-and medium activity effluents produced are much below the estimates made during the facilities' design phase. The new management allows better sorting of the effluents, based on their radioactive and chemical content. After evaporation, concentrates containing most of the effluents' radioactivity are now vitrified with high-activity wastes without increasing the volume of glass produced (see next

Table and Figure). Thanks to this process, there is no more ILW to bitumenize prior effluent discharge to the sea, as was previously the case.

*Reprocessing by-product activity*

| Percentage of activity | α | βγ (except tritium) |
|---|---|---|
| Vitrified waste | 99.5 | 97.6 |
| Hulls and end-fittings | 0.4 | 2.3 |
| Total process waste | 99.9 | 99.9 |
| Technological waste | 0.1 | 0.1 |




## 2.2.2. BROADENING THE RANGE OF OPERATION IN EXISTING PLANTS

The reference fuel considered for the design and start-up of the UP3 and UP2-800 plants was uranium oxide fuel initially enriched to 3.25% in $^{235}U$, with a burn-up of 33 GWd/t and cooled for 3 years. However, right from the very beginning of the La Hague site, AREVA NC was authorised, based on supporting studies, to use the HAO facility to reprocess other types of fuels. The UP3 and UP2-800 plants today process PWR and BWR fuels initially enriched to 3.7% in U235, with burn-up reaching 45 GWd/t, cooled for a minimal 4-year period.

The general trend is toward higher burn-ups and subsequent higher initial enrichments (up to 4.5 % or more).

MOX and RTR fuel reprocessing campaigns have been performed demonstrating the flexibility of the La Hague plant and thus its technical ability to reprocess new generations of irradiated fuel without significant modifications.

*2.3 TREATMENT/RECYCLING PLANT EVOLUTION*

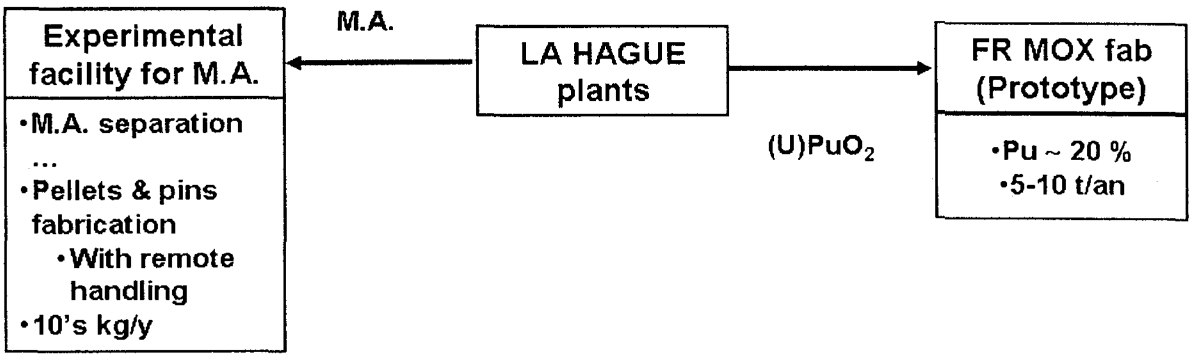
The existing workshops at La Hague (commissioned in 1990) have been designed to operate for at least forty years. With operational and technical improvements taking place on a continuous basis, they are expected to be operating, with flexibility as required, until around 2040 when GEN IV facilities (reactors and treatment facilities with advanced separation capabilities) should come on line.

In the meantime, an integrated treatment/recycling plant could be built if requested by the market. Such a scheme considering the recycling of recovered fissile materials in MOX fuel (according to needs including in fast reactors) would rely as a first step on the COEX™ process that can be implemented rapidly, and later on upgraded with other advanced processes. A COEX™ GEN III Plants is an integrated plant (in line fuel treatment/re-fabrication) with no separated plutonium (U and Pu co-extracted and kept together in solution all along the process), on line measurement of fissile materials inventory, and advanced safeguards devices.

Going back to France (see section: "the French nuclear power fleet: status and perspective" of chapter 1), the evolution of a back-end scheme and associated technologies shall be consistent and synchronized with the evolution of reactor concepts and associated nuclear fuel cycles. Studies are presently undertaken to assess the capability and the interest of using the existing treatment and recycling sites, including La Hague, to host demonstration facilities to investigate advanced actinides separation options as required by the 2006 Act on "*the Sustainable management of radioactive materials and waste*". Preliminary work has been initiated to investigate the possibility for two fuel fabrication facilities to be associated with the GENERATION IV reactor prototype:

- Manufacturing of prototype driver fuel (10 t/year capacity);
- Micro-pilot manufacturing of minor actinides bearing fuels for test irradiation (a few tenth of kg/year capacity).

The fuel cycle workshops associated with the French GENERATION IV prototype:



## 3. RESEARCH AND DEVELOPMENT FOR THE FUTURE

In France, the R&D on treatment processes is undertaken according to the national plan on radioactive materials and radioactive waste management updated every three years by Parliament according to the 2006 Act on sustainable management of radioactive materials and waste (see §1).

This plan specifies a step by step R&D programme based on 3 routes (as an extension of the roadmap already defined in the framework of the 1991 waste management Act) which complement each other:

Axe 1: Partitioning and transmutation with the following key milestones:
- 2012: assessment of GENERATION IV reactor and fuel cycle technologies and of their industrial feasibility
- 2020: operation of a prototype fast reactor

Axe 2: Geological disposal for ultimate HLW with the following key milestones:
- 2015: expected authorization for construction of the disposal.
- 2025: target date to operate the disposal.

Axe 3: R&D on very long term interim storage.

The R&D on treatment processes refers to axe 1.

The fuel cycle scenarios are developed in an evolutionary approach so as to be consistent with changes progressively to be implemented in the French nuclear power park:

- Extension of fuel burn-up in PWRs;
- Extension of plant life time;
- Parity of UOX and MOX fuels burn up;
- Step by step shutdown of old facilities and renewal of the French reactor fleet with GEN-3 PWRs (such as EPR reactors);
- Introduction of GEN-IV on the long run (by 2040) in a multi-strata scenario.

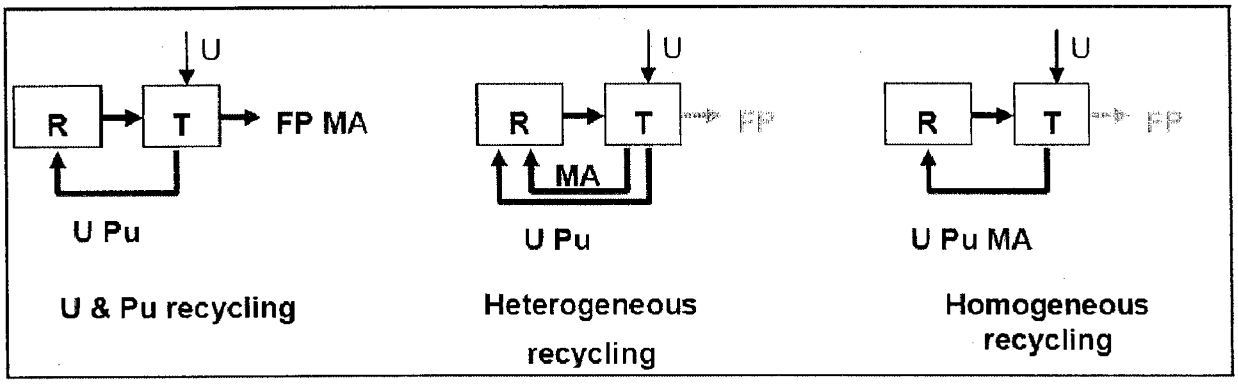
In that respect, three main fuel cycle strategies are investigated by the CEA in order to provide technical (and economically acceptable) solutions that will ease the decision taking process when appropriate:

- Optimization of U and Pu recycling strategy using existing PWRs and EPR units to be implemented in France NPP as a first step, co-management of U, Pu and possibly Np in GENERATION IV fast reactors as a second step.

- Feasibility of minor actinides (MA) homogeneous recycling in driver fuels of GENERATION IV reactors (with a low content of MA, typically 3%).

- Feasibility of MA heterogeneous recycling in about one third of the nuclear power park with a higher content of MA (typically 30%) in MOX blanket assemblies of GENERATION IV fast reactors or as target in Accelerator Driven Systems.

These three paths are symbolized in the figure below:




Since the early nineties CEA has been undertaking research and development studies on the separation (recovery) of the minor actinides (MA) – i.e. neptunium (Np), americium (Am) and curium (Cm)-contained in the irradiated fuel. The reference strategy for separating these elements from the irradiated fuel is based on an adaptation of the PUREX process for the separation of Np and the development of new liquid-liquid solvent extraction processes DIAMEX and SANEX for the others (Am, Cm).

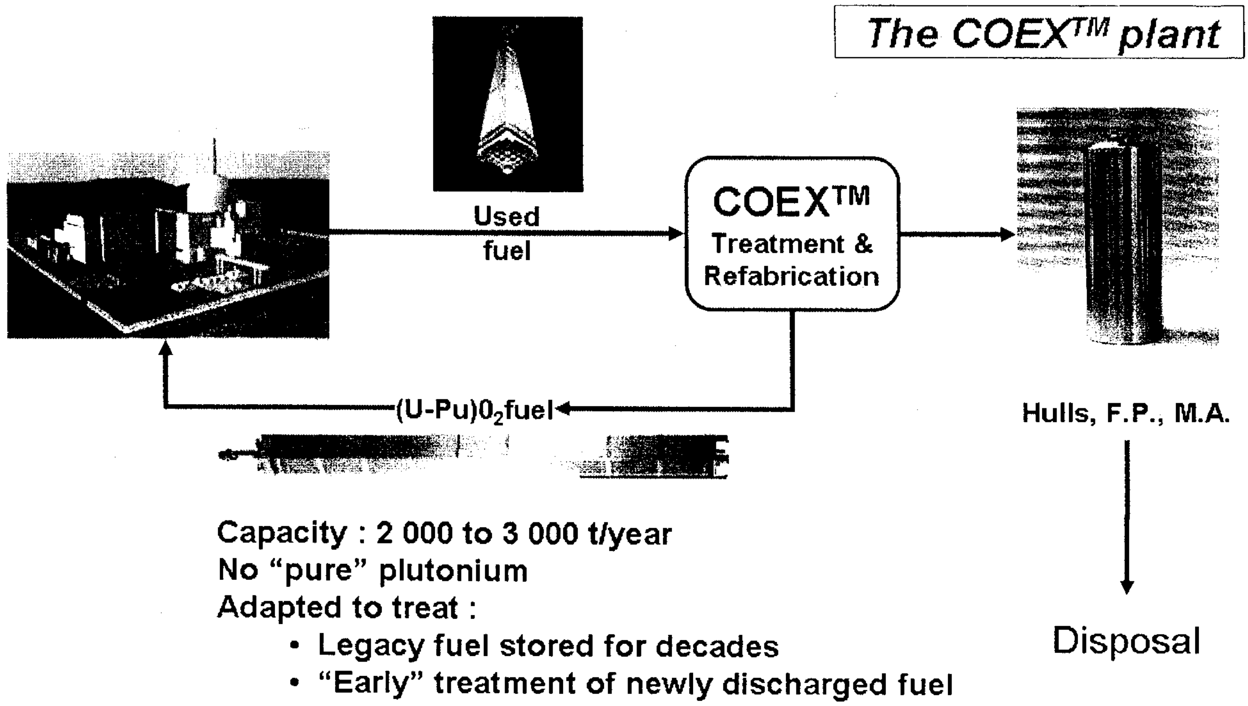
The scientific feasibility of these processes has been performed at lab-scale within year 2005 in ATALANTE (in cells equipped with pulsed columns, mixed-settlers, centrifugal contactors and Couette Effect columns), starting from about 13 kg of genuine uranium oxide irradiated fuel at around 60 GWd/t.

The next step is to further assess the implementation on industrial scale of these three types of processes obviously at different stage of development today:

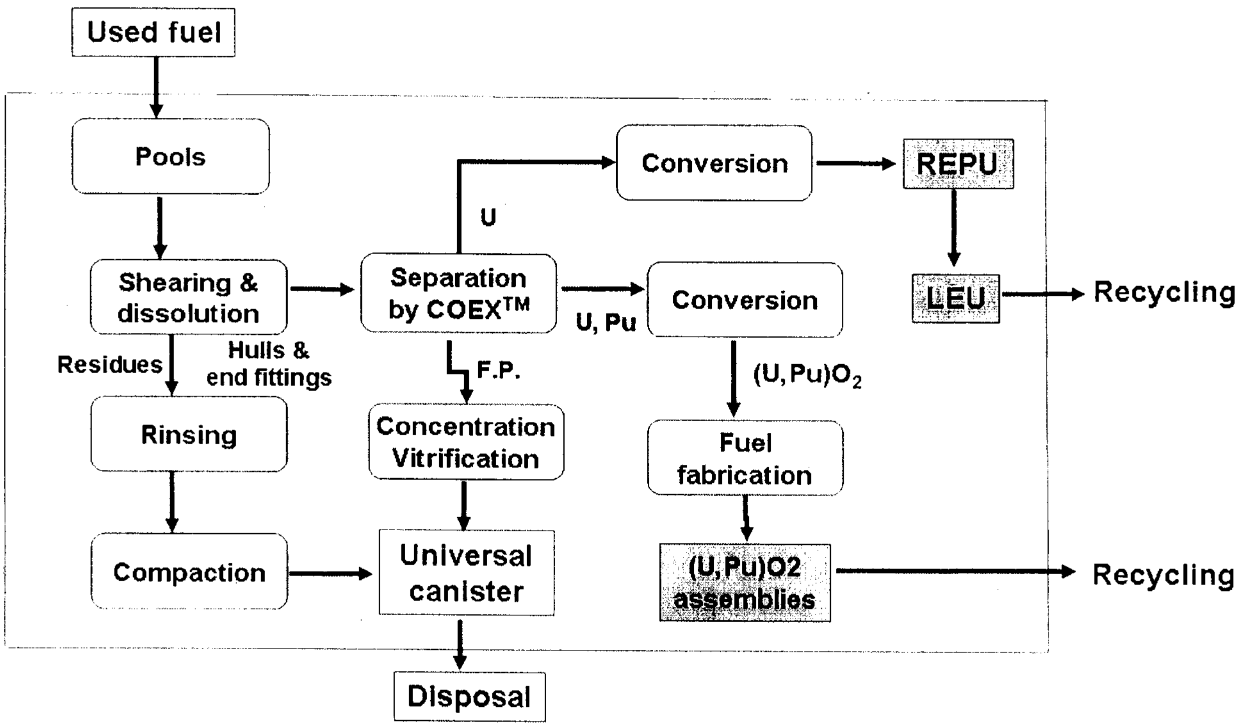
*a)* Separation processes based on co-extraction/co-conversion of uranium and plutonium (COEX™) – and possibly neptunium – are already leading to the design of GENERATION III reprocessing plants which are close to near term industrial deployment and are capable of satisfying new market needs (no pure plutonium separated, higher throughput, high MOX performances both for LWRs and Fast Reactors).

b) Selective separation of long lived radionuclides from raffinate (with a focus on Am and Cm separation) based on the optimization of DIAMEX-SANEX processes for their recycling in heterogeneous mode in GENERATION IV systems. This option b) can be implemented in combination with COEX™ process option a).

# Example of a Generation III processing facility

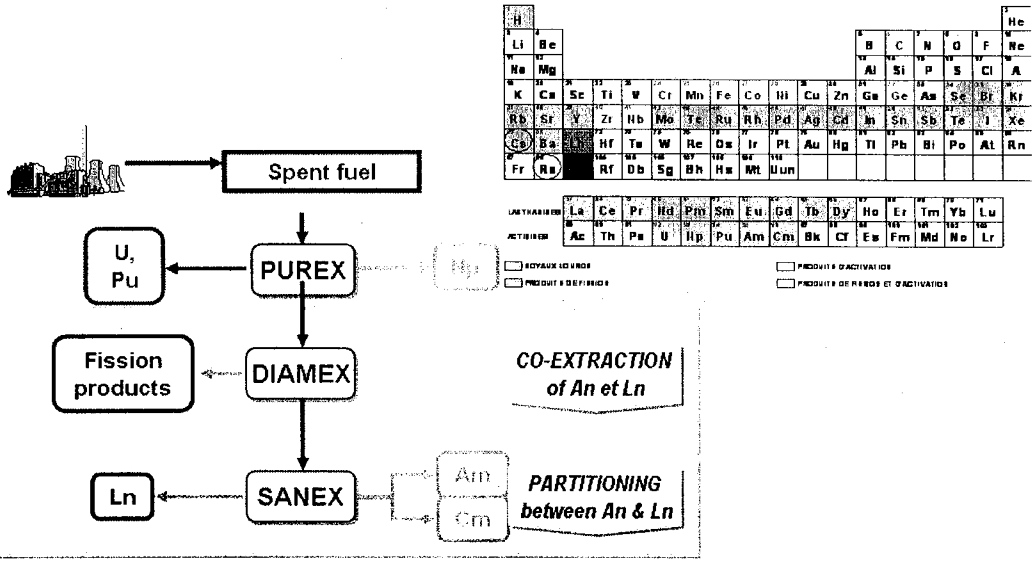



## COEX™ general flowsheet



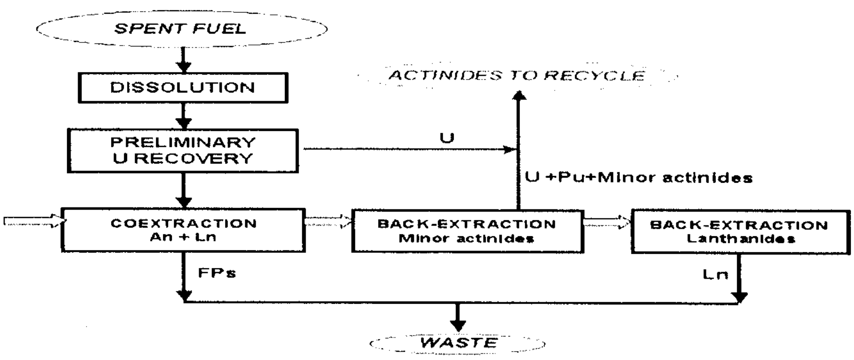

*c)* Group extraction of actinides as an alternative fuel cycle strategy to allow for the homogeneous recycling of actinides in GENERATION IV fast systems. The reference process, called GANEX, is an adaptation of the DIAMEX-SANEX flowsheet and will be tested on genuine solution in 2008.

# Actinides partitioning : research path used




*First oxalic co-precipitation of (U,Np,Pu,Am) tested in CEA Atalante facility*

**The GANEX process flow sheet**



In that respect, the key milestones for the three routes (COEX, DIAMEX-SANEX, GANEX) are:

- lab-scale process demonstration by 2009.
- Technical feasibility of the envisaged three processes to be assessed by 2012 and selection of technologies to be tested for industrial scale development with the construction of two pilot plants :
    - One dedicated to the manufacturing of the driver fuel of the GEN-IV prototype plant to be built by 2020 by CEA (possibly based on the COEX™ technology)
    - One dedicated to the production of fuel assemblies containing minor actinides which could be tested under irradiation in the MONJU fast reactor and in the French GEN-IV prototype reactor.

On the long run, the goal is to have a technology validated for industrial scale deployment of GEN-IV fast reactors by 2040.