FRENCH RESEARCH PROGRAMME TO REDUCE THE MASS AND TOXICITY OF LONG-LIVED HIGHLY RADIOACTIVE NUCLEAR WASTE

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France has launched a process of optimising waste management by separating and recycling recoverable energy materials, reducing, conditioning and storing final waste. In addition, it has initiated operations to clean up and dismantle older facilities (first-generation reactors, cycle plants, etc.) through the development of related technologies.

French research and industry have developed processes and technologies which ensure downstream management of the fuel cycle and waste (reprocessing of spent fuel, recycling of plutonium, processing and conditioning of waste from nuclear plants and cycle facilities, development of containers and interim storage facilities – clean up and dismantling).

Once operations in the downstream part of the cycle have been completed, long-lived highly radioactive waste (vitrified class C waste) represents the major portion of the waste's total radioactivity, conditioned in a small volume (<180 m^3/year of glass packages).

Research and development are being pursued with two main objectives:

- To minimise the quantity of waste produced by operations at nuclear power plants.
- To develop processes which would make it possible to condition long-lived radioactive materials in order to ensure safe and long-lasting containment in the form of moveable objects, i.e. packages, and also to study interim storage[1] or disposal[2] facilities designed to protect these packages over time.

Research primarily concerns the following areas:

- The control of plutonium, which is both an energy material and the main contributor to long-term radioactivity – studies here target progressive integration into the new fuel cycle so that

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[1] Interim storage is a management option under the responsibility of the society, in surface or underground facilities, allowing to protect the packages and to ensure recovery under conditions, which are safe and defined by technical specifications.

[2] Disposal is a solution, which could become definitive in the absence of human intervention, since the geological medium makes it possible to ensure containment on a time scale characteristic of long-lived radioactive elements.

plutonium can be recycled in pressurized water reactors on a recurring basis under economically acceptable conditions.

- Minimising long-lived highly radioactive final waste – studies here concern separation (intensive chemical separation during reprocessing for which new very selective molecules have been developed), transmutation (transformation in industrial or specialized nuclear reactors into non-radioactive elements or with a much shorter life), specific conditioning (incorporation of separated elements, which cannot be transmuted, within the crystalline network of almost unalterable materials on a time scale characteristic of disappearance through radioactive decay) of the main long-lived radionuclides (minor actinides and certain very long-lived fission products abundant in spent fuel and potentially more mobile in the environment[3]) present in highly radioactive waste;

Research is conducted with the goal of establishing by 2006 the scientific feasibility of transmutation in various types of nuclear reactors (PWR, innovative reactors) and the technical feasibility of intensive separation downstream from reprocessing at La Hague, as well as of the specific conditioning of separated long-lived radionuclides.

Studies are conducted in the framework of the French law of December 30, 1991, on the management of long-lived highly radioactive waste, which established a structured research programme with three focuses: separation-transmutation, storage in deep geological formations, conditioning and long-term interim storage.

- Focus 1 studies the various solutions envisaged to ensure a substantial reduction of the mass and toxicity of waste, for the same amount of energy produced, by separating and transmuting the waste.
- Focus 2 studies storage in deep geological formations, a situation which could become definitive in the absence of human intervention, since the geological medium makes it possible to ensure containment on a time scale characteristic of long-lived radionuclides, while maintaining for a certain period an option of reversibility so that our descendants might be able to recover the packages.
- Focus 3 concerns management procedures under the responsibility of the society, in long-term interim storage facilities above or under ground, which make it possible to protect the packages, by having previously conditioned them in a form which ensures long-lasting containment and the possibility to recover the packages under conditions that are safe and defined by technical specifications.

The law defined a calendar which stipulates that a comprehensive report evaluating research will be submitted to the French Parliament in 2006. Public authorities have designated a pilot for each focus: the French Atomic Energy Commission (CEA) for Focuses 1 and 3 and Andra for Focus 2.

This research is conducted in co-operation with partners in the nuclear industry, EdF, COGEMA and FRAMATOME, as well as with CNRS and universities. It benefits from significant co-operation at the European and international level. It is constantly evaluated by the National Evaluation Commission, which draws up and publishes an evaluation report annually.

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[3] Mainly iodine 129, caesium 125, technetium 99.

The procedure involves identifying a set of complementary scientific and technical solutions, which serve to define open and flexible strategies for the downstream part of the cycle and lay the groundwork for a decision in 2006.

Concerning partitioning research, if studies on uranium and plutonium separation from the other fission products depend on a mature chemical process, intensive separation of minor actinides and these three fission products was not possible using industrial processes. Through studies conducted since 1991, a reference programme was defined for an advanced separation process for the main long-lived radionuclides present in waste:

- Neptunium, iodine and technetium could be separated by adapting the PUREX process used industrially in the reprocessing facilities at La Hague.
- To separate americium, curium and cesium, it was necessary to develop new chemical separation processes by devising very selective molecules capable of separating these elements.

The families of extractors were defined, the principal reference molecules synthesised, and their performances verified experimentally on real radioactive solutions in the ATALANTE facility at CEA-Marcoule, in order to reach the stage of scientific feasibility (2001). The next stage will be that of technical feasibility, moving from the molecule to the overall chemical process, which will be defined and validated in 2005. The existence of the reprocessing industry makes the implementation of these processes a real possibility.

In addition, research conducted in recent years has pointed up the performances of the control of plutonium and of transmutation in different types of electronuclear power plants, showing:

- That it is possible to stabilize over time the quantity of plutonium by consuming it completely with advanced plutonium fuel; an overall balance can thus be reached between the formation and the consumption of plutonium; the amount of final waste is consequently divided by three compared with the open cycle.
- That by separating and multi-recycling the minor actinides in a reactor (in order to transmute them), the mass and toxicity of the waste is divided by 100 on a similar basis, and studies show that the innovative reactors (electricity-producing reactors or those dedicated to transmutation) which present the characteristics adapted to these performances (great capacity to consume plutonium as well as long-lived radionuclides and ability to use to the best advantage the energy contained in the fuel: rapid spectrum, fuel with a very high combustion rate, reactor/ integrated cycle, etc.).

Experimental studies on fuel for the transmutation in rapid neutron reactors have been launched, in particular in the PHENIX reactor, whose irradiation programme has focused on this research since 1998 and which has therefore been the object of inspection, renovation and maintenance, in view of a power increase in 2001.

Teams at CEA and CNRS, in cooperation with industrial partners, have provided the technical data for a request for an experimental demonstration model of a hybrid reactor for transmutation, in a European and international framework.

This research is conducted to provide, in particular with reference to the report which must be submitted to Parliament in 2006, the scientific and technical elements which may contribute to the choices and the implementation of management options for radioactive waste based on three guiding principles: the minimization of waste, containment and reversibility.

The strategy targeting the control of plutonium and the minimisation of final waste aims to achieve a significant long-term reduction in the mass and toxicity of waste to be stored and promotes progressive implementation.

- The implementation of the separation-conditioning strategy may be programmed as an extension of existing industrial capability: development, in a reprocessing facility, of complementary processes which would make it possible to carry out the intensive separation of long-lived radioactive elements, then their conditioning in specific matrixes designed to last a very long time.

- The transmutation potential of light water reactors (current and EPR to satisfy the need for new reactors), based on the development of new plutonium fuel, could be used to consume all the plutonium, with the other long-lived elements benefiting from the separation-conditioning strategy; the amount of final waste is thus divided by three compared with the open cycle.

- Future nuclear power production systems, studied in light of objectives of economic competitiveness, optimum utilisation of natural resources in fuel, significant capacity for the consumption of plutonium and long-lived radionuclides, would make it possible to reduce even further the mass and toxicity of waste to be stored.

In addition, research on conditioning, interim storage and long-term storage is conducted, in cooperation with the producers of waste and Andra, in order to develop:

- Processes for processing-conditioning for all types of nuclear waste for which an industrial conditioning process does not exist.
- Containers which are certified for long-term interim storage, compatible with recovery or final repository.
- Knowledge of the characteristics and performances of the long-term behaviour of all the packages.
- Detailed preliminary projects for interim storage facilities, above or under ground, certified for the long-term, and ready to be built if so decided, making it possible to keep spent fuel over time, in particular MOX fuel, in order to preserve the energy content and be able to carry out reprocessing-separation-transmutation operations at a later date.