EDF's Used Fuel Management French Policy – 15199

Anne Huguet, Michel Moulié, Olivier Giraud
EDF, Nuclear Fuel Division, Spent Nuclear Fuel and Radioactive Waste Management Department
1 place Pleyel, 93282 Saint-Denis (France)

ABSTRACT

Regarding back-end fuel cycle, EDF's strategy, implemented from the very beginning of French nuclear production, consists in reprocessing of used fuel; decision to recycle plutonium in French PWR was taken from 1984. This reprocessing and recycling strategy, relying on existing industrial facilities (AREVA La Hague and Melox plants), has proven to be reliable and efficient. Treatment leads to a stabilization of used fuel total inventory in interim storage. Vitrification process ensures a safe packaging for high level and long-lived waste under a reduced volume. Recycling of fissile materials saves natural uranium requirements. Concentration of Pu in MOX used fuel leaves open the option to reuse it for starting next Generation IV systems beyond 2040.

In 2008, EDF & AREVA, supported by French Government, agreed on commercial terms covering long term fuel reprocessing and recycling (up to 2040). Currently, EDF fuel management strategy relies on flow equilibrium in order to respect fuel cycle consistency and sustainability. The underlying principle is to strictly adjust separated plutonium production to recycling possibilities (i.e. licensed reactors and MOX fuel fabrication facilities). Given that fuel cycle policy, any trend in NPP core management that may impact the fuel cycle should be anticipated within times in order to avoid technical or administrative incompatibilities, and guarantee a high level of safety and robustness. In collaboration with industrial operators, EDF have to perform periodic "Cycle Impact" analyses and report to the French Nuclear Safety Authority (ASN); next exercise is scheduled by the end of 2016.

INTRODUCTION

In France, EDF is operating a fleet of 58 PWR units; an EPR unit is currently under construction.

Reprocessing of French used fuel has been implemented from the beginning of nuclear production, initially to enhance energy independence, along with fast breeder reactors program, with the prospect of an increasing worldwide demand. Reprocessing strategy enables the recovering of valuable materials, plutonium (Pu) and reprocessed uranium (RepU), which can be re-used under MOX (Mixed Oxides) and ERU (Enriched Reprocessed Uranium) products form. Decision to recycle Pu in French PWR was taken from 1984; industrial reality arises in 1987 at Saint-Laurent B. Energy equivalence with natural uranium fuel enriched at 3.7% was achieved in 2007. The loading of ERU fuel in French PWR began in 1994. Equivalence with natural uranium fuel enriched at 3.7% was achieved in 1999.

Given that reprocessing-recycling fuel cycle policy, any change in fuel management or operation should be anticipated within times in order to guarantee a high level of safety and robustness of the nuclear fuel supply chain.

EDF FRENCH NPP FLEET

EDF French NPP fleet represents a total of 58 units in operation, spread over 19 sites, representing a total installed output of approximately 63,000 MW.

EDF French PWR fleet declines into successive standardized series, incorporating improvements resulting from feedback from operating experience and optimizing the electrical power output:

- series CP0 and CPY comprising 34 plant units of approximately 900 MW;
- series P4 and P'4 comprising 20 plant units of approximately 1,300 MW;
- series N4, the most recent, comprising 4 plant units of approximately 1,450 MW;

An EPR^{TM} reactor of approximately 1,600 MW is currently under construction at the Flamanville site (FLA3).

EDF French nuclear production has reached 403.8 TWh in 2013, representing 73.5% of total electricity generation in France.

EDF IN-CORE FUEL MANAGEMENT

EDF in-core fuel management strategy consists in fitting fuel energetic performance to NPP production needs. The choice of a fuel management is the "best" compromise at a certain time between economic aims and technical constraints. The current EDF French NPP in-core fuel management schemes are given in TABLE I.

Since 2013, 24 PWR 900 MW units (CPY) are authorized to receive MOX fuel. 4 PWR 900 MW units (CPY Cruas site) are licensed for ERU fuel.

TABLE I: French NPP in-core fuel management schemes

Series	Power (MW)	Units	In-core fuel management name	Fuel type	Enrichment, Fractioning & Cycle length	Average discharge burn-up (GWd/t)
CP0	900	6	CYCLADES	UOX	4.2% per third, 16-18 months	48
CPY		28	GARANCE UNE	UOX	3.7% per quarter, 12-13 months	46
			GARANCE URE	100% URE	4.05% per quarter, 12-13 months	
			PMOX	2/3 UOX + 1/3 MOX	3.7% U, 8,65% Pu per quarter, 14 months	46
P4 / P'4	1,300	20	GEMMES	UOX	4% per third, 18 months	47
			GALICE	UOX	4,5% per third or quarter, 15-21 months	55
N4	1,450	4	ALCADE	UOX	4% per third, 17 months	47
TOTAL (in operation)	63,200	58				~ 45
EPR (under construction)	1,600	1	EPR UNE	UOX	4,2%	

Adapting the nuclear fuel cycle to support fuel core management can be challenging, especially in a reprocessing-recycling fuel cycle. From a quality perspective, the increase in burn-up fractions is leading to deterioration in the reprocessed materials, since the proportion of even isotopes, neutron absorbers, is increasing. The Pu and RepU content must be increased in the fuel assemblies in order to maintain energy equivalence with natural uranium assemblies enriched at 3.7%. Given that both Pu and RepU even isotopes also emit radiation, the increase in recycled material proportion may require modification in the fuel cycle plants.

REPROCESSING-RECYCLING FUEL CYCLE FRENCH PLICY

The French Act No. 2006-739 of 28th June 2006 on the sustainable management of radioactive materials and waste states that “reducing the quantity and noxiousness of radioactive waste is the end aim including particularly of the processing of spent fuel and the processing and drumming of radioactive waste”. This reprocessing-recycling fuel cycle strategy is now traduced in the French Environmental Code under article L542-1-2.

At the end of 2008, EDF & AREVA, supported by French Government, reached an agreement covering long term used fuel treatment and recycling (up to 2040). This framework agreement had created a stable environment for both operators.

This reprocessing and recycling strategy, relying on existing industrial facilities (AREVA La Hague and Melox plants), has proven to be reliable and efficient.

- Treatment leads to a stabilization of used fuel total inventory in interim storage, either within on-site cooling pools, or at La Hague pools.
- Vitrification process ensures a safe packaging for high level and long-lived waste under a reduced volume: a year of nuclear production leads to around 150 m^3 of glass canisters.
- Recycling of fissile materials saves natural uranium requirements.
- Concentration of Pu in MOX used fuel leaves open the option to reuse it for starting next Generation IV fast reactors, beyond 2040

Thus, the reprocessing-recycling policy constitutes a responsible and robust management solution for conditioning and storing long-lived waste, awaiting a sustainable long-term industrial solution.

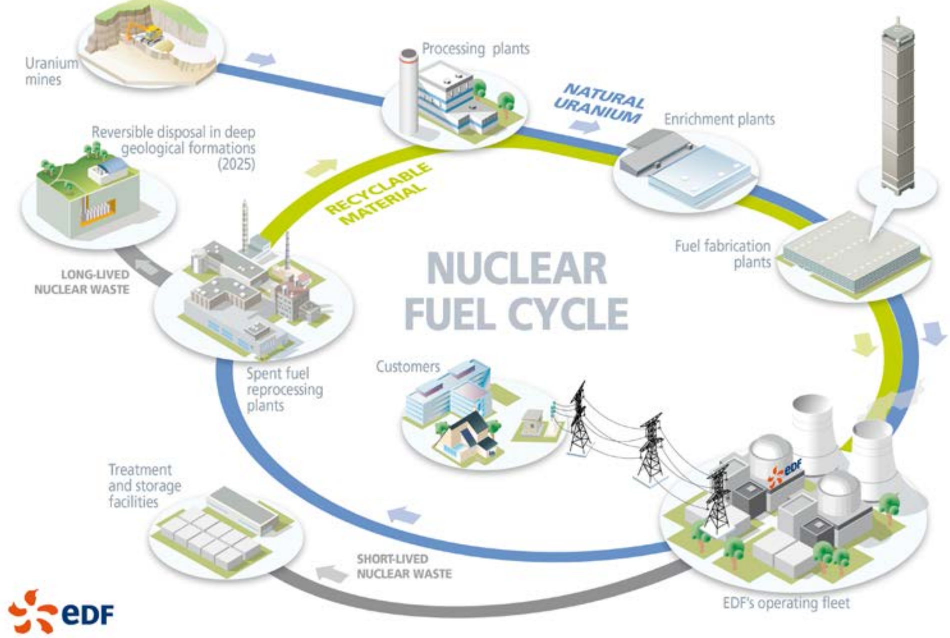

Fig-1. French PWR fuel cycle

FLOW EQUILIBRIUM PRINCIPLE

EDF is currently discharging about 1,200 t_{HM} of irradiated fuel every year.

EDF fuel cycle management strategy relies on flow equilibrium principle which consists in strictly adjust separated plutonium production to on-line recycling possibilities (i.e. licensed reactors and MOX fuel fabrication facilities). That precaution enables to limit the fissile materials Americium 241 content (coming from Plutonium 241 decay) to satisfy the requirement of the MOX fuel fabrication plant, while maintaining a sufficient buffer stock to cope with any temporary problem in the reprocessing plant.

As a consequence, the reprocessing program was set at 1,050 t_{HM}/year, leading to 120 t_{HM}/year of MOX fuel, a figure consistent with 22 MOX units loading needs. The 1,000 t/year of reprocessed uranium (RepU) is converted into U_3O_8 form which is easily stored without degradation of its energetic potential, and could be recovered for subsequent re-use, depending on the economical context.

Recent authorization of MOXing BLA3 and 4 units gained in 2013 provides operational flexibility; reprocessing flux will be coherently adjusted within the next years. French nuclear fuel cycle closure will then reached a quasi “steady-state” where the plutonium flow is balance. The RepU recycling in Cruas units was suspended in 2013; EDF is currently studying different options for restarting it at a competitive cost.

CYCLE IMPACT APPROACH

As unique French nuclear utility, EDF was asked by the French Nuclear Safety Authority (ASN) to undertake, in cooperation with main fuel cycle operators, forward-looking analyses demonstrating the overall consistency of fuel cycle industrial choices, from natural uranium conversion to radwaste management.

These “Cycle Impact” analyses aim to ensure the compatibility between potential changes in fuel characteristics and NPP core management with French fuel cycle facilities, from safety, radioprotection and waste management viewpoints: EDF has to demonstrate the absence of unacceptable effects in short and medium terms. This exercise is a mean to anticipate technical or regulatory adaptations on French fuel cycle plants or logistic, whether on front-end or on back-end operations. It enables to define fuel cycle evolution needs and priorities in terms of administrative authorization procedure and investment project development to come within the next decade.

An overall revision of the “Cycle Impact” file has been drawn up by EDF with AREVA & Andra contribution in 2008, covering the 2007-2017 period. In order to maintain an overall and constantly appropriate view of the fuel cycle evolutions, it was requested to periodically update these data through a biennale monitoring report.

Next Cycle Impact exercise, covering the 2015-2025 period, is under process; final report is due by mid-2016. It will be instructed by IRSN, ASN Technical Support Organization. The expertise report will be then examined by the Expert Advisory Committees, which will produce a series of recommendations.

CONCLUSIONS

For performance reasons, EDF is making changes to its fuel cycle management program. Guaranteeing fuel cycle consistency in such an evolving context requires forethought in order to check feasibility at each stage of the cycle. Cycle Impact initiative started by ASN enables to unite the fuel cycle stakeholders around a common objective. When examined the last Impact Cycle study, the ASN confirmed the importance of this forecast exercise.