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Prospective inventory of radioactive materials and waste produced by the French nuclear fleet according to different plutonium muliple recycling options in the frame of the french law for waste management

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In accordance with the French Act of 28 june 2006 on the sustainable management of radioactive materials and waste, the CEA in partnership with EDF, Orano and Framatome, has studied prospective scenarios using different fuel cycle options: open cycle, recycling of plutonium and uranium in PWRs (current option for the French nuclear power fleet), multiple recycling of plutonium in SFRs and multiple recycling of plutonium in PWRs.

This information has been submitted by the CEA to the Ministry of Energy within the scope of Article 51 of the Ministerial Order dated 23 February on the French National Radioactive Materials and Waste Management Plan (PNGMDR).

Rather than suddenly switching over to the large-scale deployment of fast reactors as assumed in past scenarios, it is now deemed preferable to ensure the progressive implementation of this technology through successive phases: each phase involves the more significant deployment of fast reactors with its own growth objective.

Phase A corresponds to the current state of the French nuclear reactor fleet wherein plutonium and uranium are recycled in mixed-oxide (MOX) and enriched reprocessed uranium (ERU) fuels in pressurised water reactors (PWR).

Phase B consists in recycling spent MOX fuel from PWRs in a limited number of SFRs. The objective of this phase is to stabilise the quantities of spent MOX fuels from light water reactors.

Phase C is designed to be able to stabilise the plutonium inventory by deploying a symbiotic fleet comprising UOX-PWRs, MOX-PWRs and SFRs.

The objective of phase D is to deploy a fleet of reactors that no longer burns natural uranium. There are two possible options for a nuclear fleet that can generally be considered as self-sufficient, i.e. D1, a homogeneous fleet with 100% SFRs, and D2, a mixed fleet comprising breeder SFRs producing plutonium and PWRs fuelled with 100% MOX to burn this plutonium.

A phase 0 was also defined. This phase corresponds to a hypothetical French fleet having operated in an open-cycle configuration only.

However, SFRs may not become economically competitive in the next few decades if uranium resources remain readily available, and MOX spent fuels may start to pile up at the back-end of the fuel cycle unless alternative plutonium management solutions in PWRs are found. In this study, advanced fuel batches, called CORAIL and MIX, are applied to enable multiple recycling in standard PWRs. The main objectives of these scenarios consist in fast recycling of all spent MOX fuels and in stabilizing the plutonium inventory as well as all spent fuel stocks.

For this first study, we consider CORAIL assemblies composed of 181 UOX rods and 84 MOX rods (a mixture of plutonium and depleted uranium). This configuration was studied in the early 2000s. As the enrichment of UOX rods is maximised at 5%, the plutonium content is adapted to make up for its loss of fissile quality with each recycling phase.

MIX assemblies consist of identical rods filled with plutonium and enriched uranium to a content in U235 suited to compensate for the isotopic degradation of plutonium. Three plutonium contents have been considered in our study : 8%, 9.54% and 12%.
The intial conditions of the scenarios corrsponds to the current French fleet with its 58 PWR units generating around 420TWhe per year. This annual electricity production was taken as being constant over time. A future reactor lifespan (PWRs and FRs) of 60 years is considered. A lifespan of 50 years was assumed for the fuel cycle plants (reprocessing and manufacturing).
For scenarios involving the progressive deployment of SFRs, the start-up of commercial SFRs is expected occur 25 years after the industrial commissioning of the Astrid-600 MW reactor (assumed in this study to be in 2039), i.e. in the mid-2060s. This timescale takes into account the need for sufficient feedback from the operation of Astrid and for realistic lead times for technical and regulatory actions.
For scenarios involving the multiple recycling of Pu in PWRs, it has been considered that the industrial deployment of CORAIL and MIX concepts would be theoretically possible in 2045, a timescale that seems at this stage in the studies to be reasonable for qualification of these new fuel products.

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Country or International Organization

France

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