

Fuel cycle strategies and plutonium management in Europe

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Abstract

An overview of current nuclear power generation and fuel cycle strategies in Europe is presented, with an emphasis on options for the management of separated plutonium in the medium to long term. Countries which have opted for reprocessing of spent fuel have had to contend with increasing inventories of separated plutonium. Of the various potential options for utilisation or disposition of these stockpiles, only light water reactor (LWR) mixed-oxide (MOX) fuel programmes are sufficiently technologically mature to be fully operational in several European countries at present. Such reprocessing-recycling programmes allow for a stabilisation of the overall separated plutonium stocks, but not for a significant reduction in the stockpile. Moreover, the quality of recycled plutonium decreases at each potential step of re-irradiation. Therefore, optimised or new ways of managing the plutonium stocks in the medium to long term are required. In the present overview we consider the most promising options for reactor utilisation of plutonium in both near-term future reactor and Generation IV systems.

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1. Introduction

At the beginning of the 21st century the worldwide future of nuclear power generation looks brighter than it has for many years. The form of any potential nuclear renaissance in Europe will undoubtedly have at its core the goal of sustainability over as broad a spectrum of policy areas as possible, addressing issues such as environmentally sound waste management, diversity of electricity supply, non-proliferation of nuclear weapons, economic competitiveness and social acceptance. In every one of these fields, the importance of the question of what is to be done with the plutonium which has arisen, and which will continue to arise, as a result of current nuclear fuel cycle strategies should not be underestimated.

In the early days of nuclear power technology, plutonium was considered by many in the industry as something of a panacea for mankind's energy needs. Continuous burning, breeding and recycling in a fleet of fast reactors would obviate the need for uranium mining and enrichment, perhaps even one day entirely replacing fossil fuels. It was this kind of thinking that led to two distinct but related R&D programmes being undertaken through the 50s and 60s: the separation of the plutonium built-up under normal thermal reactor operation from spent uranium oxide fuel, and the development and deployment of fast reactor systems. While both technologies proved to be technologically feasible,

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we find ourselves in a position today where industrial-scale reprocessing of plutonium exists in several countries, but fast reactor programmes are all but obsolete. The net result of this is a continuously growing stockpile of separated civil plutonium.

As fast reactor programmes were shutdown during the last 20–30 years, the only plutonium recycling option that remained available was based upon thermal plutonium re-utilisation in light water reactor (LWR) systems. This programme benefited greatly from the fuel research undertaken for fast reactor technology, leading to the utilisation of mixed-oxide (MOX) fuel in LWR systems. A large-scale industrial programme now exists in several European countries based upon the so-called reprocessing–recycling MOX strategy. This strategy is not currently optimised in terms of plutonium utilisation, and serves only to prevent any further build-up of the separated plutonium stocks, without offering a possibility to decrease these stocks. Therefore, a wide and varied research programme has evolved in the last decade or two in order to achieve more effective utilisation of plutonium stocks in LWR systems. Furthermore, as the future of nuclear power has continued to look brighter, more novel solutions involving new generations of high-temperature gas-cooled reactors and fast reactor systems have been considered.

On the opposing side of the argument over the future of separated plutonium – a side which considers that the plant safety, interim storage and overall proliferation risks associated with plutonium based fuel cycles are too high – the preferred solution is disposition of the separated plutonium stockpile followed by geological disposal. Research in this area is focussed on identification of suitable matrices to host the plutonium and modelling of the behaviour of these waste-forms in repositories over geological time periods. Due to a stronger resilience to heat generation and radiation damage the most promising matrices for plutonium and minor actinides have been identified as ceramics, such as zirconolite (Ewing, 2005). While it is accepted that disposition of this type will be required for a fraction of current European stocks of separated plutonium which are not well-suited to reactor utilisation (such as contaminated samples), the exclusive focus in the current overview is on fuel cycle strategies involving reactor utilisation.

2. Nuclear fuel cycle strategies in Europe

At early 2007, 15 of the 27 countries in the European Union (EU27) employ a total of 145 nuclear power units in order to help meet their electricity generation requirements. Representing 31% of total electricity generation capacity in the EU the nuclear contribution amounts to around 132 GWe. (Switzerland generates a further 3 GWe in five power units.) Table 1 shows a breakdown by country of nuclear generating capacity, number of nuclear generating stations and reactor type. One immediately sees that light water reactors (pressurised water and boiling water reactors, with the acronyms PWR and BWR) dominate the European nuclear landscape, with Britain (MAGNOX and AGR, both

Table 1
Nuclear generating capacity and reactor type across Europe

Country	Reactor type	Number	Net electric power (MWe)
EU27			
Belgium	PWR	7	5801
Bulgaria	PWR	2	1906
Czech Republic	PWR	6	3500
Finland	2 PWR/2 BWR	4	2696
France	PWR	59	63,363
Germany	11 PWR/6 BWR	17	20,339
Hungary	PWR	4	1755
Lithuania	RBMK	1	1185
Netherlands	PWR	1	485
Romania	CANDU	1	650
Slovakian Republic	PWR	5	2040
Slovenia	PWR	1	696
Spain	6 PWR/2 BWR	8	7446
Sweden	3 PWR/8 BWR	10	8976
United Kingdom	4 MAGNOX/14 AGR/1 PWR	19	10,982
Total		145	131,820

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