

Nuclear Fuel Cycle and Materials Technologies

Objective

To strengthen the capabilities of interested Member States for policy making, strategic planning, technology development and implementation of safe, reliable, economically efficient, proliferation resistant and environmentally sound and secure nuclear fuel cycle programmes.

Uranium Production Cycle and Environment

Uranium, the heaviest naturally occurring element in the Periodic Table, is the basic raw material currently used to produce nuclear fuel. The growth potential of nuclear power will, in fact, depend on the adequacy of uranium resources. To survey the current world situation, the Agency organized an international symposium on Uranium Production and Raw Materials for the Nuclear Fuel Cycle in Vienna in June. The symposium, held in cooperation with the OECD/NEA, World Nuclear Association, Nuclear Energy Institute and the UNECE, was held at a time when the uranium industry is poised for a take-off after a slump of nearly two decades characterized by low prices and mine closures. The increased demand for uranium has led to a near tripling of uranium prices over the last three years. As a result, new exploration and mining activities have been initiated and the major uranium producers have increased their annual production.

The consensus of the participants was that uranium resources, including both primary and secondary supplies, are adequate to meet the immediate projected demand of uranium to fuel expanding nuclear power programmes up to the year 2050 and beyond. However, the gap between uranium in the ground and the availability of yellow cake (uranium concentrate) has to be narrowed. Airborne and ground exploration based on new geophysical techniques could pave the way for discovering deeper uranium deposits that do not have a surface expression. In addition, new mines and mills are required. Expansion of in situ leach (ISL) mining activities and the development of smaller, more efficient equipment for use in deep underground mining were some of the technological pathways that were highlighted to ensure the timely delivery of uranium concentrate to the market place.

The biennial IAEA–OECD/NEA “Red Book” – *Uranium 2005: Resources, Production and Demand* – introduced a new categorization scheme for resources for consistency with the UNECE’s terminology for reporting fossil energy and mineral resources (Fig. 1):

- ‘Inferred resources’ replaces EAR-I (‘Estimated Additional Resources Category I’);
- ‘Prognosticated resources’ replaces EAR-II (‘Estimated Additional Resources Category II’);
- ‘RAR (Reasonably Assured Resources) + inferred resources’ are now referred to as ‘identified resources’.

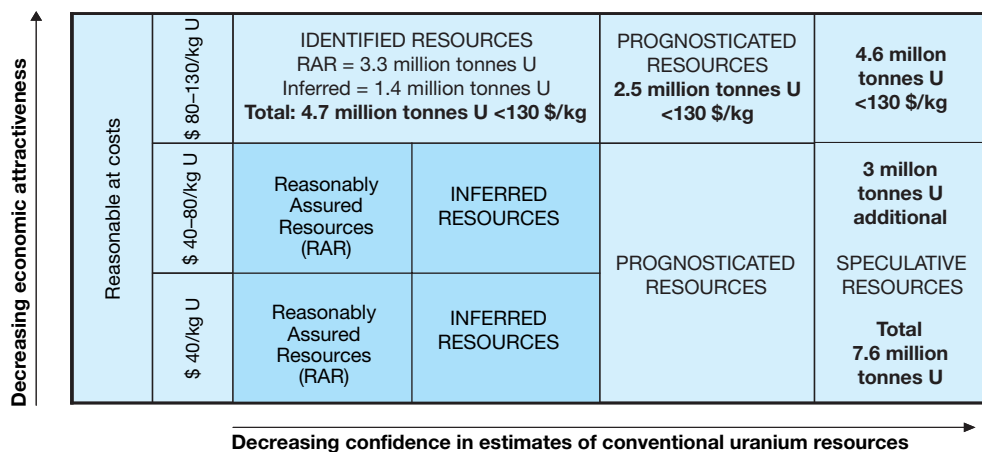


FIG. 1. Classification scheme for conventional uranium resources.

Beginning in the early 1990s, the worldwide exchange of information on uranium resources and production began to improve dramatically. The Agency took the lead in providing forums, particularly for developing countries, to discuss uranium resources and production capabilities. The proceedings of two such forums were published in 2005: *Developments in Uranium Resources, Production, Demand and the Environment* (IAEA-TECDOC-1425) and *Recent Developments in Uranium Exploration, Production and Environmental Issues* (IAEA-TECDOC-1463).

Given the increasing importance of ISL mining, the Agency also published a *Guidebook on Environmental Impact Assessment for In Situ Leach Mining Projects* (IAEA-TECDOC-1428). Aimed at both companies planning uranium development and the authorities that will assess such developments, the report provides advice on each of the three main guidelines for an environmental impact assessment: justifying the proposed practices, limiting effluents and optimizing protection and safety.

In addition to sharing information and giving advice and guidance to Member States, the Agency provides assistance through its technical cooperation programme. For example, in 2005, expert teams visited three Member States and provided:

- Assistance on exploration techniques and prospecting for sandstone-type uranium deposits;
- Training for personnel in the use of special software for the digital documentation of drill holes;

- Training for personnel in mineralogy and the geochemistry of uranium deposits.

Nuclear Fuel Performance and Technology

The trend of increasing fuel burnup, with higher ratings and longer dwell time in nuclear power plants, requires improved modelling of fuel behaviour (Fig. 2). A CRP which studied fuel modelling at extended burnup (FUMEX-2) was concluded. Its central accomplishment was to significantly extend the capability of fuel codes used in Member States to accurately predict fuel performance at high burnups, both for normal operation and under transient conditions.

Another CRP completed in 2005 – ‘Data Processing Technologies and Diagnostics for Water Chemistry and Corrosion Control in Nuclear Power Plants’ (DAWAC) – provided a better understanding of water chemistry control for efficient and safe plant operation with increased fuel burnup, longer fuel residence times and fewer failures. Specifically, the CRP led to improvements in both analytical models and operational practice using the information developed on water chemistry control techniques, plant chemistry, corrosion diagnostics and plant monitoring of corrosion, chemistry and coolant activity.

To assist Member States in developing tools to assess fuel reliability, the Agency launched a new CRP on delayed hydride cracking (DHC) in

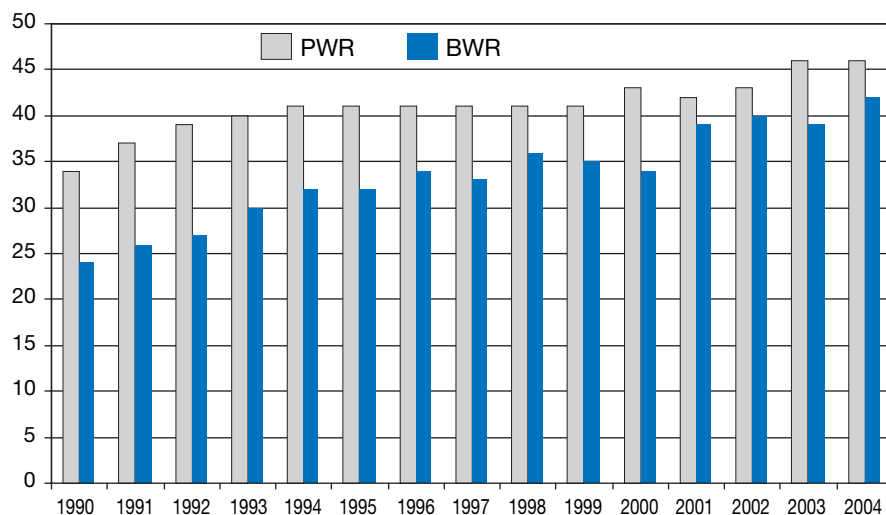


FIG. 2. Average discharge burnup (in GW-d/tonnes uranium) at nuclear power plants in the USA, 1990–2004.

zirconium alloy cladding materials. In 2005, the pin loading tension testing methodology for the CRP was established and pre-hydrated zircaloy-4 samples were distributed to ten participating laboratories for round robin measurements of DHC velocity. The study will apply comparable procedures for studies of a variety of cladding materials of different origins.

Management of Spent Fuel from Power and Research Reactors

Half a century of experience with the storage of spent fuel, together with continuing technical advances, means that political and public deliberations on its ultimate disposition can be thorough and informed. At the beginning of 2005, 190 000 t HM (tonnes heavy metal) of spent fuel were in storage facilities around the world; capacity must be provided for an additional 8000 t HM per year for the immediate future. An accelerated global expansion of nuclear power will add to that estimate.

The Agency plays a central role in building up the technical knowledge base for the long term storage of power reactor spent fuel. Its efforts have included a series of CRPs on spent fuel performance assessment and research. The latest CRP held its initial Research Coordination Meeting in 2005 to review national activities on long term spent fuel storage and specific research proposals. Other important meetings convened by the Agency addressed advances in applications of burnup credit to enhance spent fuel transport, storage, reprocessing and disposition, and the handling of damaged fuel. The latter reviewed past experience and existing practice, and prepared recommendations for handling damaged spent fuel. A further meeting, in the Republic of Korea, on spent fuel treatment options reviewed alternative technologies and applications.

A new publication — *Technical, Economic and Institutional Aspects of Regional Spent Fuel Storage Facilities* (IAEA-TECDOC-1482) — elaborates on one of the options in the report of the Director General's Expert Group on Multinational Approaches to the Nuclear Fuel Cycle (see the Safeguards chapter). States that have small nuclear power programmes or only research reactors, and hence no possibility for early disposal, face the challenge of arranging extended interim storage of their spent nuclear fuel. Access to an interim storage facility provided by a third country would be a desirable solution, and

the report concludes that the regional concept is technically feasible and economically viable.

Argentina, Brazil, Chile, Mexico and Peru share the problem of adequately managing the spent fuel from their research reactors which have been in operation for several decades. The fuel from these reactors has been in temporary storage in reactor pools and there are no final disposal facilities in these countries at the moment. In response to these concerns, the Agency implemented a regional technical cooperation project on the management of spent fuel from research reactors. Some of the major achievements of this project were the establishment of national capabilities for the characterization and monitoring of spent fuels, and publication of a report on options for the back end and management of spent fuel.

Information Systems and Related Issues

The Agency's NFCIS web site (<http://www-nfcis.iaea.org/>) consists of the Nuclear Fuel Cycle Information System (NFCIS), World Distribution of Uranium Deposits (UDEPO), Post-Irradiation Examination Facilities (PIE) and the Nuclear Fuel Cycle Simulation System (VISTA). Another database on Material Properties of Minor Actinides (MADB) is currently being developed. An example of the information contained in NFCIS is shown in Fig. 3. The database also includes facilities that are shut down, in standby or being planned.

A Technical Committee Meeting on 'Fissile Material Management Strategies for Sustainable Nuclear Energy' was organized in Vienna in September. Three key issues papers were presented: uranium demand and supply through 2050; fissile material management strategies for sustainable nuclear energy, including backend fuel cycle options; and sustainable nuclear energy beyond 2050. The meeting provided a comprehensive review of global uranium resources, emphasized the need for augmenting uranium exploration, mining and milling, and highlighted the relative merits of different fuel cycle options.

The reprocessing of spent fuel in several countries has generated large inventories of reprocessed uranium (RepU) and plutonium. The Agency initiated activities to provide Member States with information on the status of RepU and viable options for its use, and the status and viability of recycling plutonium in the form of inert matrix

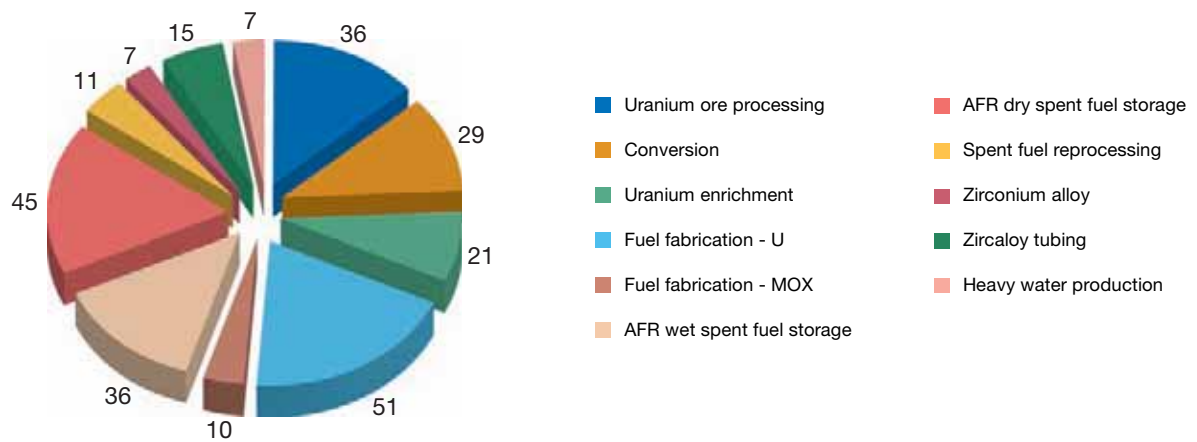


FIG. 3. Number of operating nuclear fuel cycle facilities in 2005. (AFR: away from reactor; MOX: mixed oxide.)

fuels (IMFs) for burning plutonium and reducing inventories. The inert matrixes under consideration are aluminium, zirconium, magnesium and their oxides and mixed oxides, silicon carbide, zirconium alloys and stainless steel. Reports on RepU and IMF are in the final stages of review and publication.

The liquid metal cooled fast reactor (LMFR) and its fuel cycle can play an important role in ensuring efficient use of uranium and thorium raw materials, and in reducing radiotoxicity in the final waste for geological disposal. To promote information exchange and collaboration, the Agency organized a technical meeting in Obninsk, the Russian Federation, on LMFR fuels and fuel cycle options. The status of mixed uranium plutonium oxide conventional fuel and advanced LMFR fuels, namely mixed uranium-plutonium monocarbide, mixed mononitride, and U-Pu and U-Pu-Zr metallic fuels, and their reprocessing by aqueous and pyro-routes, were discussed. One of the conclusions of the participants was that for the short term, i.e. through 2030, mixed oxide fuel was the preferred option. For the longer term, advanced fuels with higher heavy metal density (for better breeding) are under consideration, including metal and nitride fuels.

Inert matrix fuels are being considered for burning actinides, in general, and for the disposition of plutonium, in particular.

Thorium is three to four times more abundant than uranium. In the early years of nuclear energy generation, there was considerable interest in thorium to supplement uranium reserves, but interest waned with the discovery of new uranium deposits and as nuclear expansion slowed. More recently, interest has revived due to such issues as proliferation resistance, longer fuel cycles, higher burnup, improved waste form characteristics, reducing plutonium inventories and in situ use of bred-in fissile material.

Over the past years, a number of States have embarked on national programmes to reduce the use of high enriched uranium (HEU) in their civilian nuclear fuel cycle. An Agency publication — *Management of High Enriched Uranium for Peaceful Purposes: Status and Trends* (IAEA-TECDOC-1452) describes the conversion of 31 research reactors from HEU to LEU fuel, the Russian Federation's programme to reduce research reactor fuel to less than 20% uranium-235, and fuel repatriation programmes of the Russian Federation and the USA. ■