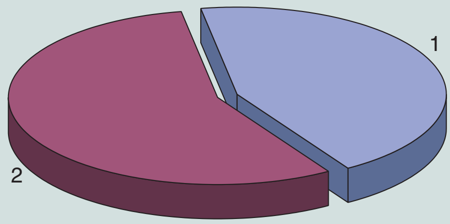
NUCLEAR FUEL CYCLE AND WASTE MANAGEMENT TECHNOLOGY

PROGRAMME OBJECTIVE

To have the latest fuel cycle and waste management strategies adopted in an increasing number of Member States and related state of the art technologies in place in an increasing number of facilities; and to facilitate the planning and implementation of safe, sustainable, cost efficient and environmentally sound nuclear fuel cycle and waste management activities in Member States.

Regular budget expenditure:$5 018 868

Extrabudgetary programme expenditure (not included in chart): $609 508



1. Fuel Cycle and Materials: $2 201 109
2. Waste Management and Technology: $2 817 759

KEY ISSUES AND HIGHLIGHTS

- The latest edition of the IAEA–OECD NEA “Red Book” — *Uranium 2001: Resources, Production and Demand* — was published. A complementary report, *Analysis of Uranium Supply to 2050*, was also published by the Agency.

- Key milestones were achieved in the areas of: mixed oxide (MOX) fuel technology; water chemistry and corrosion control in nuclear power plants; and zirconium alloy degradation by hydrogen.

- With fuel storage periods in some instances becoming longer than originally foreseen, the Agency focused on issues connected with long term dry storage, the implications for fuel fabrication and burnup credit.

- Initiatives to address the issue of geological repositories and the lack of infrastructure and resources to implement available technologies in many developing Member States included: the creation of an ‘International Network of Centres of Excellence for Demonstration and Training in Geological Disposal’; and an international conference on the management of radioactive waste from non-power applications.

FUEL CYCLE AND MATERIALS

A new edition of the "Red Book" — *Uranium 2001: Resources, Production and Demand* — was completed and published jointly with the OECD NEA. The Red Book is the foremost world reference on uranium supplies, and includes projections of nuclear energy growth through 2020 and implications for uranium supply and demand. The Agency also published a complementary study, *Analysis of Uranium Supply to 2050*. This study considers both primary supplies (newly produced uranium) and secondary supplies (from reprocessed fuel and surplus nuclear weapons). The report concludes that known resources are adequate to satisfy primary supply requirements through about 2034 in a middle demand case, after which currently speculative, undiscovered resources would need to be developed. Figure 1 shows the projected shortfall in market based production assuming that high enriched uranium (HEU) from nuclear weapons will not be available after 2023 and excess inventories will have been drawn down to strategic levels. Known resources are adequate to satisfy market based requirements to 2034. Cumulative production derived from known resources is adequate to satisfy 80% of total market based production requirements to 2050.

A new report, *Manual of Acid In Situ Leach Uranium Mining Technology* (IAEA-TECDOC-1239), examines in situ leaching (ISL), a relatively new mining approach with both economic and environmental advantages for extracting uranium from suitable sandstone type deposits. ISL has accounted for 13–15% of world output in recent years and is expected to grow further given its low costs and environmental advantages. This document covers uranium geology, geo-hydrology, chemistry, reservoir engineering and process engineering.

In the area of nuclear fuel performance and technology, the Agency began a new CRP on data processing technologies and diagnostics for water chemistry and corrosion control in nuclear power plants (DAWAC). The goal of this project is to develop and implement the most effective systems to collect, evaluate, process and diagnose water chemistry data for a variety of nuclear power plant designs.

Delayed hydride cracking can result in the failure of pressure tubes in CANDU reactors and may contribute to fuel cladding failures in

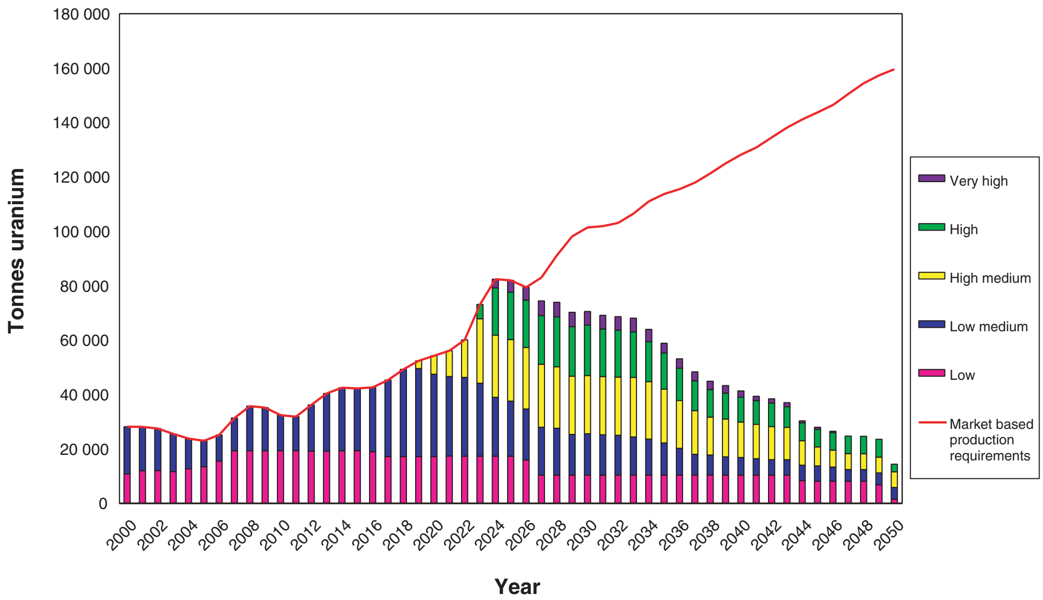


FIG. 1. Projection of market based production from a study of reasonably assured resources by cost category — middle demand case.

LWRs. In a CRP on hydrogen and hydride degradation of zirconium alloys, the Agency completed a round robin exercise to address the difficulties of accurately measuring hydrogen concentrations in zirconium alloys at the low levels often of practical importance. A major outcome of this exercise was an improvement in the techniques used at several participating laboratories.

To address fuel safety issues under sharp transients and accident conditions, the Agency convened a Technical Committee meeting to: review current experimental programmes; analyse the validity and applicability of existing loss of coolant (LOCA) and reactivity initiated accident (RIA) criteria; assess existing databases; and determine needed criteria revisions and new experiments. The participants made recommendations on revising existing LOCA and RIA criteria as they apply to licensing procedures. Licensing criteria dealing with enthalpy deposition for RIAs, for example, may no longer be valid and may require rethinking, both in terms of limit values and whether they actually target the correct failure mechanism.

Spent fuel is accumulating at about 10 500 tonnes of heavy metal (t HM) per year worldwide. Only one third of this is reprocessed — the remaining two thirds must be stored. With storage periods becoming longer, it will be necessary in the near future to extend the licences of existing storage facilities. The long term behaviour of spent fuel and materials during storage is also becoming increasingly important.

In this connection, the Agency completed a CRP on Spent Fuel Performance Assessment and Research (SPAR) dealing with the behaviour of spent fuel and structural materials during long term storage. The principal conclusions were that extending the period of interim storage is a general trend in the countries participating in the CRP regardless of the policy adopted for closing the ‘back end’ of the nuclear fuel cycle. However, extending the storage period requires knowledge of fuel evolution during very long term storage and the behaviour of the storage system. It is therefore important to maintain the continuity of knowledge for fuel assemblies during the entire fuel cycle and to have a system for registration and documentation using a data storage medium that can be read and used well into the future, i.e. longer than 100 years. In general, the wet storage performance of LWR fuel is excellent. In dry storage, no degradation mechanisms are known and no detrimental experience has been reported. Dry storage has become a mature technology, with almost 20 years of favourable experience for spent power reactor fuel and about 30 years for research reactor fuel. It is important to have dense concrete structures that keep free water to a minimum, making them less vulnerable to freeze–thaw cycles. However, monitoring technologies are particularly important for the long term storage of spent fuel, including monitoring of fuel cladding and component integrity, as well as containment system integrity.

Using extrabudgetary funds, the Agency modified the COBRA-SFS code for use on PCs and held a training workshop to apply the modified code. With this code, countries with WWERs can perform thermal-hydraulic calculations for both cask/container and multivault dry storage systems directly on PCs.

More than 90% of all research reactor fuel is clad in aluminium and stored in water. A CRP that studied the corrosion of such fuel in water was completed. One conclusion was that suboptimal water quality is a major cause of localized corrosion that can eat through the cladding. A number of research reactors already have such leaking fuel. The CRP determined the optimum water chemistry conditions to minimize corrosion. The results have been disseminated to Member States and have already had an appreciable impact on water chemistry control at several facilities.

In the last five years, 674 tonnes of HEU have been declared surplus to defence programmes. A Technical Committee meeting in November analysed the impact of this material on the uranium production market. It was concluded that low enriched uranium blended down from HEU plays an essential role in maintaining the supply of civil uranium resources. In addition, there were still a number of research reactors using HEU.

To date, more than a million tonnes of depleted uranium (DU) have accumulated as a result of enrichment operations. The Agency addressed this issue jointly with the OECD NEA, producing a report that focused on the management of DU. Among the issues discussed in this report were the length of time that DU could be stored, in what form it would be stored and the implications of its final disposal.

Recent changes in nuclear fuel markets, particularly as a result of market liberalization and expanding nuclear programmes in Asia and Eastern Europe, have created the need for up to date information on national and international fuel cycle activities. In response, the Agency published *Country Nuclear Fuel Cycle Profiles* (Technical Reports Series No. 404), which offers national profiles that can be used by both experts and the public.

WASTE MANAGEMENT AND TECHNOLOGY

Radioactive wastes arising from the operation of nuclear installations require timely and effective management. To this end, accurate assessments of radioactive wastes from all sources are necessary, and safe, cost effective and environmentally sound technologies should be made available for Member States to manage and dispose of their nuclear waste. A related area is decommissioning technology for nuclear power and research reactors. For example, some 200 currently operating research reactors are at least 30 years old and will soon be candidates for decommissioning. Many are in Member States where decommissioning experience may not be readily available.

A CRP that ended in 2001 focused on how decommissioning technology could be improved, adapted or optimized for the specific needs of research reactors. Examples include the development or adoption of simpler decommissioning technologies in place of purchasing costly equipment, such as remote handling equipment. One observation of the CRP was that there is now a trend towards early planning for decommissioning. This was in contrast to the widespread belief in the past that resources required for decommissioning would be readily available whenever needed. This resulted in inadequate planning for decommissioning, including insufficient provision for the required infrastructure (e.g. the absence of decommissioning oriented regulations) or financial resources. Another issue was that despite the maturity of the nuclear decommissioning technology/industry, at least in developed countries, there were still some areas where more work was needed. Thus, technological developments were needed in the treatment and disposal of decommissioning wastes, particularly medium and high activity materials. There is also a clear desire on the part of individual Member States to develop their own decommissioning technologies. This is partly due to the need to understand the effects of decommissioning under site specific conditions in order to satisfy the nuclear regulators, and partly because many processes are proprietary formulations that are expensive to buy on the open market. Achieving the proper balance between developing project and country specific technologies and purchasing technologies in the open market remains a serious challenge for many countries.

To help Member States improve systems, programmes and activities that support nuclear applications and the fuel cycle, including the legacy of past practices and accidents, the Agency established a new *Directory of Radioactively Contaminated Sites* (DRCS). It covers past environmental contamination from the production and processing of nuclear materials, mining, milling, weapons testing, inadequate waste management, and accidents involving nuclear materials. Documentation was also published describing the content, functionality and conceptual layout of the DRCS.

Most Member States have to provide for the safe management of institutional radioactive waste, and many also have to manage naturally occurring radioactive material wastes and disused radioactive sealed sources. 'Management of Radioactive Waste from Non-Power Applications: Sharing the Experience', an Agency conference held in Malta in November, enabled States without nuclear power programmes to share information and learn from experience gained in countries with nuclear power plants. The conference recommended enhanced co-operation to solve technical, organizational and regulatory problems, and emphasized the role of the Agency in co-ordinating these efforts. In particular, it was recommended the Agency: promote good practices for the management of different types of waste; encourage innovative technology development; organize training and provide methodological support in the management of specific wastes; and set risk levels and standards.

Thousands of tonnes of radioactive graphite and carbon waste are by-products of the decommissioning of an entire generation of graphite moderated nuclear power and research reactors. In addition, its high chemical stability makes irradiated graphite difficult to process for final disposal. An Agency study concluded that the wide variety of graphite forms, contamination levels and physical and chemical characteristics do not permit a universal solution for waste processing and disposal. Management difficulties arise due to the large volume of contaminated graphite and the presence of certain radionuclides (tritium and carbon-14). In addition, high levels of Wigner energy stored in the graphite lattice may lead to problems during processing as well as disposal. On the positive side, the good mechanical properties and relatively high chemical stability of graphite were noted, permitting simplification of the waste conditioning process. In the light of these facts, it was concluded that the processing and disposal of graphite wastes need to be considered on a case by case basis.

Many Member States are engaged in, or planning, the near surface disposal of low and intermediate level waste, creating a need for information and guidance. The Agency has been studying the relevant technologies and issues concerning the development, siting, safety and performance assessment, and implementation of disposal systems. Non-technical concerns, including socioeconomic, institutional, local and national infrastructure, public policy, acceptance and quality management issues have also been addressed. Reports were completed on: *Characterization of Groundwater Flow for Near Surface Disposal Facilities* (IAEA-TECDOC-1199); *Technical Considerations in the Design of Near Surface Disposal Facilities for Radioactive Waste* (IAEA-TECDOC-1256); *Procedures and Techniques for Closure of Near Surface Disposal Facilities for Radioactive Waste* (IAEA-TECDOC-1260); and *Performance of Engineered Barrier Materials in Near Surface Disposal Facilities for Radioactive Waste* (IAEA-TECDOC-1255).

The Agency has a particularly important role to play in fostering co-operation, advancing research and building public confidence in the overall science and technology of disposing high level, long lived radioactive wastes in deep geological repositories. Underground research laboratories (URLs) have a central contribution to make to this effort. For three decades several Member States have conducted extended experimental and demonstration programmes in URLs, providing valuable assessments of potential disposal systems in various geological environments. In order to disseminate this information on a wider basis, the Agency published *Use of Scientific and Technical Results from Underground Research Laboratory Investigations for the Geological Disposal of Radioactive Waste* (IAEA-TECDOC-1243). The opportunity to share expertise, promote international consensus on geological disposal and expand expertise through training and hands-on experience in URLs was offered to the Agency by Belgium, Canada and the USA. These States have been designated as the founding members of the 'International Network of Centres of Excellence for Demonstration and Training in Geological Disposal', which was officially established by the Agency in 2001. The objective of the network is to facilitate the transfer and preservation of knowledge and technologies, supplement national efforts to resolve key technical issues and promote public confidence in waste disposal schemes.

In the area of predisposal management of radioactive waste from nuclear applications, a new training programme in the quality management of radioactive waste was initiated with an emphasis on quality assurance. The plan is to select waste management facilities in different regions that will host training sessions for waste management operators and regulators.

One of the Agency's major tasks is to assist Member States in rendering spent radium sources safe. Such assistance was provided in 2001 to Ethiopia, Indonesia, Lebanon, Philippines, Slovenia, Thailand, Zambia and Zimbabwe. The Agency's newly developed

'International Catalogue of Sealed Radioactive Sources and Devices' is an essential component of this expert advice. The catalogue now includes basic technical data, design features and illustrations for more than 1800 radioactive source models and 300 devices, as well as the address and company history of more than 900 manufacturers and distributors. In addition, two technical documents were published in support of these Agency advisory and assistance projects — *Management for the Prevention of Accidents from Disused Sealed Radioactive Sources* (IAEA-TECDOC-1205) and *Waste Inventory Record Keeping Systems (WIRKS) for the Management and Disposal of Radioactive Waste* (IAEA-TECDOC-1222).

Information collection and dissemination efforts included the release in July of the new 'Net Enabled Waste Management Database' (NEWMDB), which contains waste management information from correspondents nominated by Member States. Data have been collected on national radioactive waste management programmes and organizations, plans and activities, relevant laws and regulations, policies and radio-active waste inventories.

The Contact Expert Group (CEG) for International Co-operation in Radwaste Management with the Russian Federation — for which the Agency acts as the Secretariat — continued to promote and co-ordinate efforts to improve the management of spent nuclear fuel and radioactive waste. In 2001, several new projects were initiated. The first focuses on the Andreeva Bay ex-navy technical base located on the north shore of the Kola Peninsula, which was used for more than 30 years to store radioactive waste and spent nuclear fuel from submarines. About 100 submarine reactor cores have been accumulated and stored in conditions that require improvement. In October, a CEG workshop reviewed Russian technical information and developed project proposals that were formally endorsed by the CEG in November, with negotiations on these projects starting thereafter. Another project deals with the commissioning of two new installations for liquid radioactive waste treatment, one at the Atomflot enterprise in Murmansk (built with the co-operation of Norway and the USA), and the other at the Zvezda plant near Vladivostok (built with Japanese assistance). These installations are designed to eliminate all radioactive releases into the sea during submarine decommissioning. Other projects that have been endorsed by the CEG include rehabilitation of the Murmansk RADON centre and construction of a repository for solid radioactive waste at the Novaya Zemlya Archipelago.

Agency technical co-operation projects are designed to enhance the organizational capabilities of Member States. This is of particular importance for reactor decommissioning, which is a multidisciplinary process requiring an integrated approach that makes optimum use of national and international resources. In this regard, several projects achieved significant milestones during the year. In Slovakia, the Agency provided expertise and training on remotely operated and robotic equipment for decommissioning the A-1 nuclear power plant. Another project focused on developing plans and the necessary infrastructure for decommissioning Ukrainian WWERs. The Agency is also assisting Lithuania in planning for the decommissioning of Unit 1 of the Ignalina nuclear power plant. Through these projects information and know-how on active decommissioning was transferred to States *planning* decommissioning activities. In addition, financial considerations and other impacts of decommissioning were highlighted.

Building capacity in Member States to manage radioactive waste is another important aspect of the Agency's technical co-operation programme. A new project focuses on uranium mining in Portugal, studying numerous small mining and milling sites as well as a former radium processing site. It will also assess and quantify the potential environmental impacts of these sites.