CHANGING GLOBAL PERSPECTIVES

NUCLEAR FUEL CYCLE TRENDS INTO THE NEXT CENTURY

BY NOBORU OI AND LOTHAR WEDEKIND

At a time when more countries are facing rising energy demands and environmental challenges, the role that nuclear power can play in the safe and clean production of electricity is receiving closer attention. At the same time, changing conditions are affecting the plans of the world's nuclear power industries and redefining the technology's future development.

Over the past twenty years, the question of how nuclear power should be technically and commercially developed has changed significantly. It was once widely believed among scientific and technical experts that a closed fuel cycle would be the most desirable option – in other words, the fuel from power reactors would be reprocessed after its initial use, and plutonium would be recovered from the spent fuel for recycling as fuel in "fast-breeder" reactors. In turn, these reactors would produce more plutonium that could be used for fuel in other reactors. So closed, the nuclear fuel cycle offered the promise of a long-term and competitive energy technology.

But conditions changed, and the past two decades have brought a set of "new realities" to the table. They include the fact that the generation of electricity from nuclear power has grown at a far slower rate than expected. Second, there currently is limited interest in fast-breeder reactors and delay in their commercialization where they are being developed. Third, the adoption of a closed nuclear fuel cycle has not taken hold as once envisaged, and where it is the chosen option, it has been only partially achieved. These new realities have contributed to the accumulation of plutonium in civilian programmes, and a rising inventory of spent fuel in storage. In addition, as the result of the end of Cold War, there may soon be a large amount of plutonium from dismantled warheads transferred into the civilian sector, thus adding to these inventories.

At the global level, countries are working together to address specific policy and technical issues that these changing conditions have raised, and to more clearly define common areas for global cooperation. One major forum was the International Symposium on Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities, convened in June 1997. More that 300 experts from 40 countries and five international organizations took part. It was organized by the IAEA in cooperation with the European Commission (EC), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA), and the Uranium Institute (UI). *(See box, page 11.)*

This article highlights selected aspects of the major topics examined at the symposium. The topics were considered in depth by six symposium working groups, each of which presented conclusions reflecting the international common understanding of the status and trends affecting the development of the nuclear fuel cycle well into the next century.

THE GLOBAL ENERGY OUTLOOK

This working group, under the chairmanship of Mr. H. F. Wagner of Germany, examined nuclear energy over the long term. Their key conclusions included:

- The supply of uranium for nuclear power reactors will probably be sufficient to satisfy

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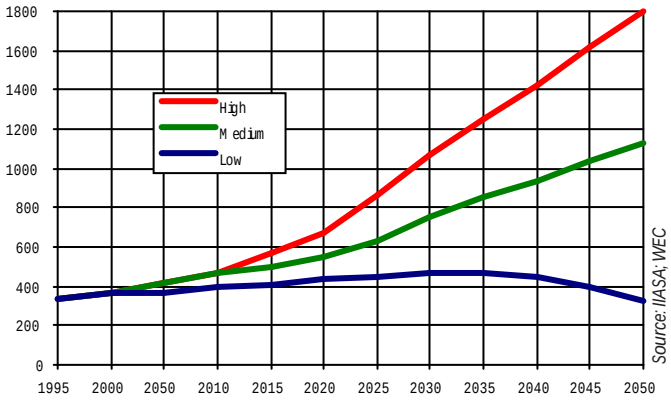
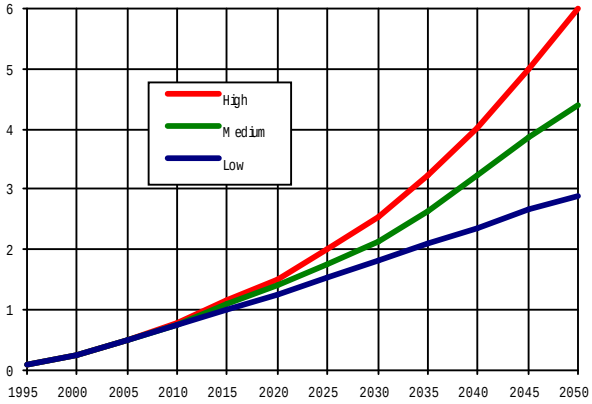
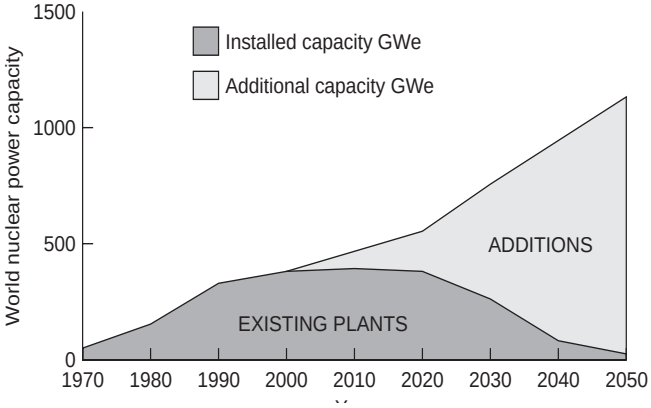
WORLD NUCLEAR CAPACITY SCENARIOS



PROJECTED CUMULATIVE NATURAL URANIUM REQUIREMENTS UP TO THE YEAR 2050



PROJECTED NUCLEAR CAPACITY REQUIRED UNDER IIASA/WEC MEDIUM VARIANT



worldwide programme needs up to the year 2050. Three nuclear energy scenarios were considered, based on studies by the International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC), and they were characterized as "contrasting but not extreme". *(See graphs.)* Projected cumulative natural uranium requirements for the years 1995-2000 were compared with published levels of resources in the publication *Uranium Resources, Production and Demand*, commonly known as the "Red Book". In the case of the medium variant, the group found there may not be sufficient uranium resources to cover the years after 2050 for reactors existing then if one assumes that these reactors will have a total lifetime of up to 40, perhaps up to 60 years. Therefore, the ways and means to make better use of uranium resources, and the potential influence of steps taken, are of importance.

■ A number of technical measures offer promising options for the better utilization of uranium resources. They include increasing the burnup of nuclear fuel during reactor operations, the lowering of tails assays in the depleted stream of fuel enrichment operations, and recycling plutonium. About 25% of all uranium resources can be saved by reducing the tails assay from 0.3% to 0.15%, compared with a saving of about 17% by recycling all plutonium in light-water reactors. Both options are achievable from a technical and industrial viewpoint.

■ Over the long term from a worldwide perspective, strategies and technologies targeted at more efficient uses of uranium resources will probably have to be considered before 2050.

PLUTONIUM MANAGEMENT

The second working group, chaired by Mr. A Gloaguen of France, considered the present status and immediate prospects of plutonium management.

The production, storage and use of plutonium have been the subject of international concerns but there is no common

international understanding on what policies should be adopted. In the late 1970s, the International Fuel Cycle Evaluation (INFCE) was conducted with the participation of 40 countries and four international organizations to examine non-proliferation aspects of different fuel cycles. The review showed that effective measures can and should be taken both at the national and global levels and agreements worked out to minimize the danger of proliferation of nuclear weapons – without jeopardizing energy supplies or the development of nuclear energy for peaceful purposes.

Key conclusions of the symposium working group include:

- Since INFCE some 20 years ago, not very much seems to have changed as far as policy is concerned. Most countries that decided to pursue reprocessing/recycling programmes have not changed their positions since then. A large and viable recycling industry has been established in Europe and is being developed in Japan.
- Key technologies are available for the effective management of both the closed and open nuclear fuel cycles, and for the disposition of surplus military plutonium. Many of these technologies have been implemented.
- At the end of 1996, the inventory of separated civil plutonium amounted to about 150 tonnes, and it is expected to increase to about 170 tonnes by the end of 1999 before dropping to about 150 tonnes by the year 2015. Under free market conditions for plutonium, the inventory could be reduced to about 50 tonnes by 2013. This does not include the amounts of plutonium that Russia and the United States have in excess of their defense needs and may release into the civilian sector.
- The inventories of separated plutonium are expected to be reduced by the use of modern fuel fabrication plants for producing mixed-oxide fuel (MOX) and the licensing of light-water reactors to burn MOX fuel.
- Medium- and long-term spent fuel storage can be carried out at both "at-reactor" sites and "away-from-reactor" sites.
- International transparency measures in the management of plutonium are important to provide accurate information to the public and build international confidence.

OCCUPATIONAL COLLECTIVE DOSES OF THE THREE FUEL CYCLE OPTIONS (PER 400 TERAWATT-HOURS), EXCLUDING RADIOACTIVE WASTE DISPOSAL

	Occupational Exposure	Main Contributors
Once-Through Fuel Cycle	153 man.Sv	Reactors 69%; mining/milling 29%
Mixed-oxide (MOX) (Recycling in thermal reactors)	147 man.Sv	Reactors 72%; mining/milling 26%
MOX-FR (Recycling in thermal and fast reactors)	139 man. Sv	Reactors 76%; mining/milling 22%

FUEL CYCLE AND REACTOR STRATEGIES

Chaired by Mr. D. Meneley of Canada, this working group examined the timeframe up to the year 2050 for fuel cycle and reactor strategies. Key conclusions include:

- The dominant trend in the commercial market for nuclear power plants will be characterized by a slow evolution of present reactor types and designs. The background for this conclusion is that high investment costs, a strict regulatory climate, and the need for high performance over a long period of time dictate a very conservative approach for most nuclear plant buyers.
- The expansion of nuclear power will depend on three basic issues: governmental and public interest, economic competitiveness, and the beneficial role which nuclear energy might be called upon to play in sustaining the world's healthy environment.
- Water reactors will continue to play a significant role during the next 50 years and beyond.
- In the case of recycling plutonium in thermal reactors, there are limits to the number of possible recycles. Multiple recycling produces degraded plutonium which limits the number of recycles in thermal reactors to two or three. Such degraded plutonium can, however, be used as a fuel in fast-breeder reactors. If such reactors, or other effective plutonium burners, do not materialize, spent fuel will still end up in final repositories.
- Although the goal of sustainable nuclear energy production can be achieved most

effectively by fast-breeder reactors, their introduction may not be seen in the competitive electricity market until after the year 2030, when they could account for only about one to two percent of projected nuclear energy capacity.

HEALTH & ENVIRONMENTAL IMPLICATIONS

A fourth working group, chaired by Mr. J. Lochard of France and Mr. B. Loewendahl of Sweden, examined the health and environmental implications of the different fuel cycle options. Key conclusions include:

- In normal operation, there are no significant differences in terms of human health and environmental safety impacts among the nuclear fuel cycle options considered. *(See table, page 9.)*
- A remaining issue common to all three fuel cycles is the potential for major accidents which may have significant health and environmental consequences. The prevention of such accidents calls for a high level of vigilance and an ongoing improvement of safety.
- Long-term storage and disposal of spent fuel or radioactive waste do not raise any particular problems in terms of health. Individual exposure remains at extremely low levels as long as no intrusions into the disposal sites occur.
- Plutonium toxicity is not a major factor in the context of normal operational impacts. Certainly, however, there is much misconception about this issue, which has been often used as a strong argument against the fuel cycle, including reprocessing of nuclear fuel.

ASPECTS OF NON-PROLIFERATION & SAFEGUARDS

Under the chairmanship of Mr. H. Kurihara of Japan, this working group considered non-proliferation and safeguards aspects related to the nuclear fuel cycle. Its key conclusions included:

- The nuclear non-proliferation regime is becoming increasingly effective. Additional demands placed upon the regime must be adequately funded by the international community.
- The nuclear non-proliferation regime needs continuous adaptation to "new realities" affecting nuclear power development. Two good examples are the IAEA's safeguards development programme through which the verification system was strengthened, and initiatives for the verification of surplus military materials transferred into the civilian sector.
- A main issue facing the nuclear non-proliferation regime over the next decades is the extent to which the IAEA will be involved in the verification of surplus military material and how this, and other demands on the safeguards systems, will be resourced. New technical and institutional approaches will be required.
- In the context of reactor and fuel-cycle choices and future technological development in the civil nuclear power sector, the nuclear non-proliferation regime should be able to provide the necessary assurances, irrespective of the nuclear technology chosen, and should not constrain future choices.

INTERNATIONAL COOPERATION

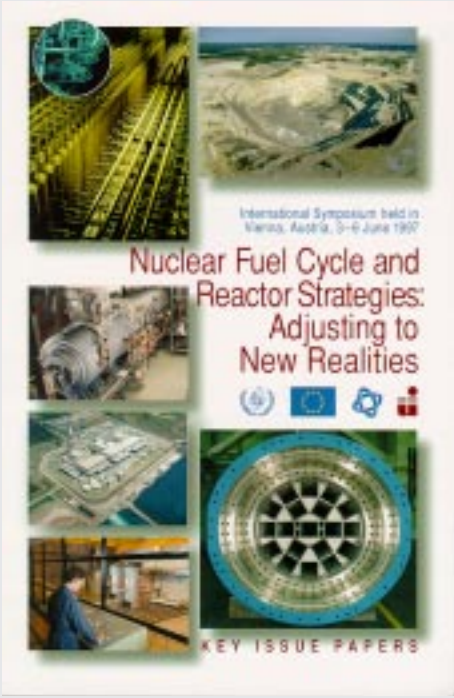
Chaired by Mr. M. Kratzer of the United States and Mr. I. Kouleshov of Russia, the sixth working group considered aspects of international cooperation. Its key conclusions included:

- International co-operation has been an essential factor and a principal driving force in the development and application of nuclear power. The most distinctive feature of this co-operation — the nuclear non-proliferation regime — has successfully limited the spread of nuclear weapons to a level far below those once predicted.
- The supply of nuclear materials, equipment, and technology for peaceful uses by States possessing them to other States has been one of the major and most impressive successes of international co-operation.
- The arrangements and mechanisms in place for international co-operation are generally adequate to meet current and future needs. However, improvements are desirable in a number of areas, such as the disposition of surplus military plutonium, development of fast-breeder reactors, regional fuel cycle centres, international plutonium storage, and the transparency of plutonium management.
- The IAEA should explore appropriate steps to ensure the exchange of basic information on major developments, and economic and programmatic information on the fuel cycle, possibly through establishing a regular mechanism of such exchange in close cooperation with other international organizations.

SYMPOSIUM OVERVIEW

The International Symposium on Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities provided an in-depth picture of energy, economic, and technological developments shaping the future.

A Steering Group of senior experts from twelve IAEA Member States and two international organizations directed the Symposium's organization over a number of years; it was chaired by Mr. M. Kratzer of the United States. Additionally, six Working Groups prepared six key issue papers with the participation of over 70 experts from 12 States —Argentine, Canada, China, France, Germany, India, Japan, Russia, South Africa, Sweden, the United Kingdom and the United States — and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, the European Commission, the International Energy Agency, and the Uranium Institute. These papers represented the common international understanding on various aspects of nuclear fuel cycle and reactor strategy, with particular reference to the issue of plutonium, up to the year 2050, and were the result of two years of intensive work by the experts.



Altogether, more than 300 experts from 44 countries and five international organizations participated in the symposium, which received extrabudgetary financial support from Japan. In addition to the six issue papers, 24 invited papers were presented and 45 poster presentations were made. Also featured were addresses by leading experts and policy makers in the field, and the key issues were explored in discussions by the participants and a panel of experts from India, Republic of Korea, Japan, France, Germany, Russia, the United Kingdom, and the United States.

The IAEA recently published the symposium's key issue papers in its Proceedings Series and, in December 1997, issued the orally presented papers as a Technical Document (IAEA-TECDOC-990).

CONTINUING THE DIALOGUE

In summary, the symposium served as a valuable forum for examining the new realities and choices facing countries utilizing nuclear energy. The six key issue papers presented at the symposium summarized the common international understanding of the various fuel cycle issues, including those related to technology, safety, safeguards, environmental and institutional developments.

The symposium also served to heighten interest in continuing the dialogue at the global level, in light of the importance of issues being faced and nuclear power's established and potential role in contributing to world electricity supplies. Toward this end, the IAEA in early 1998 set up the International Working Group on Nuclear Fuel Cycle Options. Among topics that the Group will cover are the advantages and disadvantages of different fuel-cycle strategies of plutonium and waste management, which will play a key role in the future development of nuclear energy.

In the final analysis, the ongoing evolution of Agency programmes related to the nuclear fuel cycle must reflect the realities confronting the international community today, including the security and commercial impacts of ex-weapons material. Moreover, the activities will have to be geared to promoting further the reliability, safety, and economic viability of nuclear power to help interested countries meet electricity demands well into the next century. ❑