International Conference on Nuclear Power and Its Fuel Cycle (2–13 May 1977)

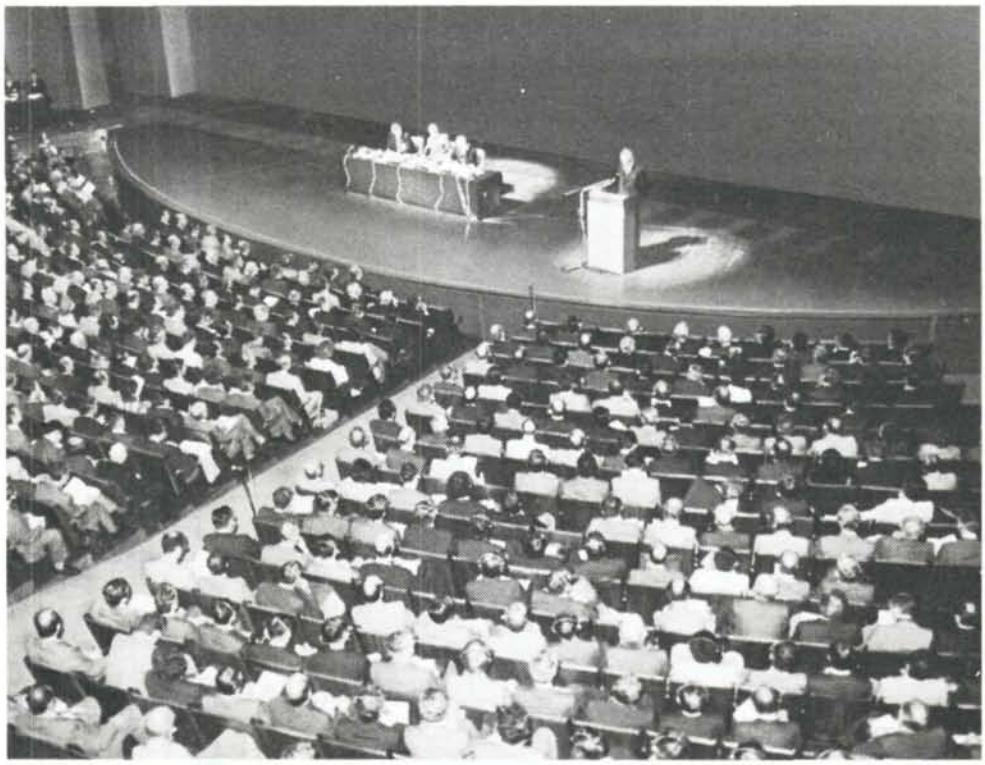
Renewed Confidence in Nuclear Power

At the final session of the International Conference on Nuclear Power and Its Fuel Cycle, Dr. Sigvard Eklund, Director General of the IAEA, in his closing speech highlighted some of the more important topics dealt with during the conference. His remarks were based on summaries of sessions provided by the chairmen of the sessions, scientific secretaries and members of the IAEA Secretariat, who selected what they considered to be the gist of important contributions and conclusions.

The background against which this conference has been set included the assumption of a need for a major commitment to nuclear power. I believe that the participants in this conference will leave with feelings of re-affirmed confidence in that commitment.

This may be a somewhat striking conclusion in the face of the doubts, re-assessments, slow-downs and uncertainties which have marked the last few years and which may remain with us for some time. Yet in spite and perhaps because of them, we have seen a general agreement emerge from our discussions that nuclear power is a necessary and irreplaceable source of the future energy supply in mankind for both the short and the longer term. Of special importance has been the confirmation by the United States of their commitment to nuclear power based on light-water reactors.

This agreement stemmed from another consensus, namely, that world energy needs will rapidly grow over the next decades, although there may be some question about the rates and extent of this growth. What is certain, however, is that the present world consumption of about six billion tons of oil equivalent will increase to about twice to three times this level by the year 2000. This will happen even if the maximum efforts at conserving energy are applied by industrial countries as they should be and the most efficient methods for conversion and final utilization are developed throughout the world. It should be pointed out in this context that energy conservation measures also have a long lead time and are, in some cases, capital intensive.



The opening ceremony of the International Conference on Nuclear Power and Its Fuel Cycle was held in the auditorium of the Festspielhaus, which also was the site of the plenary sessions of the conference. The President of the Republic of Austria, Dr. Rudolf Kirchschläger, opened the conference.

The developing countries, representing more than half of today's world population, were unanimous in holding that the glaring gap between the standards of living of their nations and those of the industrial States must be reduced. This would require an expansion of energy consumption which, by the turn of the century, would raise their relative share far beyond the current level of 10 percent of the total.

It is against this background of growing needs that the role of nuclear power was assessed and I believe that there was general agreement on the following two points:

- In the short term nuclear power offers an immediate substitute for the oil and gas used for electricity production and represents for many countries deficient not only in hydrocarbons, but also in coal resources, a substantial alleviation of their dependence on foreign imports.
- In the longer term it holds out to the world a technologically mature solution to its increasing energy needs and places a safety net under the future development of mankind; for the ultimate potential of solar energy remains difficult to assess and nuclear fusion is still at a laboratory stage.

It is true that the present objectives of many nations for nuclear power development have become lower than they were a few years ago, due to the economic recession, efforts at conservation and delays in licensing and constructing power plants, and sometimes due to public opposition.

For the world as a whole, the indicated ranges of nuclear power capacity are of the order of 200 000 MWe for 1980, 900 000 MWe for 1990 and 1 300 000 MWe for the year 2000. The share of nuclear power which is today less than 10 percent of electricity and less than 3 percent of primary energy will grow to some 35 percent of electrical energy and 15 percent of primary energy by the turn of the century.

Some arguments have been advanced that since we are dealing with such relatively modest fractions of total energy needs, nuclear power might be indefinitely deferred and conventional fuels might take up the slack until all doubts and uncertainties are removed.

I believe that this type of argument misses three fundamental points:

1. Even the present minimum nuclear objective would result in saving 1.5 to 2 billion tons of oil per year by the year 2000, which is more than half of total world oil consumption now. Parenthetically, we should recall that when the demand for oil becomes greater than the supply, one can foresee the price rocketing which will follow.

2. If nuclear power is to provide a general insurance against energy shortages beyond the end of the century, it must rest on a solid basis of experience. This can only come from the operation of a large number of proven reactor types. Such avenues as breeding through various fuel cycles, which would increase the utilization of uranium resources by close to two orders of magnitude, must also be kept open. Development of reactors for high temperature would permit nuclear power to go beyond electricity production.

3. We know by experience how long it takes for a new power technology to make a significant contribution to the energy market and to build its fuel and – more important – its human infrastructure. To argue that these infrastructures could be dismantled and then suddenly called back into being when the need for them becomes acutely felt is to fly in the face of all scientific and technical advance.

Another point which was repeatedly stressed during this conference is the extreme variety of the energy situations prevailing both in industrial and developing countries. They range all the way from such cases as Italy whose total indigenous fuel resources would hardly be sufficient to meet two years of consumption at present rates, to the USA and the USSR which have vast oil, gas and coal reserves. Hence, the nuclear policies of these countries are bound to be different. Nevertheless, under the diversity of immediate concerns, there seems to be unanimity on the long term need for more energy. We will need all available energy sources, and therefore, research development on new sources should be encouraged.

It is this unanimity, combined with a growing recognition of the close international links of the nuclear industry where no country can be an island, that gives us grounds to hope that some of the major issues which I will now briefly review will be successfully resolved.

REACTOR TECHNOLOGY

In this century, the main contribution to nuclear capacity will be provided by the light-water reactors with a share also taken by the heavy-water reactors. There is evident progress towards standardization for these reactor designs in the size range 900 to 1300 MWe for light-water reactors and 600 to 750 MWe for heavy-water reactors. It should still be possible to improve the general availability and reliability of nuclear power plants although they have shown performance parameters which over long periods are comparable with or

better than fossil-fired plants in the same size range. In difficult situations such as hard winters, nuclear plants have shown high reliability and availability and have demonstrated the advantages of independence from outside fuel supplies. The economic advantages compared with oil- and coal-fired plants have clearly been demonstrated over long periods, in spite of increasing capital costs.

While the pressure-vessel type, light-water reactors appear unlikely to be taken to larger unit sizes than about 1300 MWe, it was interesting to learn that in the USSR the channel type of boiling-water-cooled, graphite-moderated reactor, which benefits from modular design and construction, is now being built in a 1500 MWe unit with plans for units up to 2400 MWe.

The USA is considering the indefinite deferral of reprocessing and plutonium utilization and a delay in the commercial introduction of the plutonium fast breeder. Most other countries, especially those without abundant indigenous uranium resources, are planning to close the light-water-reactor fuel cycle; some five countries are aiming at large scale introduction of plutonium breeders before the end of the century. One developing country plans for a closed domestic light-water fuel cycle in about 15 years from now.

Liquid-metal-cooled, fast, plutonium breeders are now entering their third generation with the construction of the 1200 MWe Super Phénix project in France and the 1600 MWe project in the USSR. The safety of these breeders is comparable to the present thermal reactors.

There has been a re-awakening of interest in technical studies concerning other advanced reactor systems, notably the high-temperature reactors and the breeders using the thorium-uranium-233 cycle. Their development could be followed by the production of hydrogen as a secondary fuel. Plans are being formulated for using nuclear power for the combined production of electricity and of heat at low and high temperatures, which also could be used for desalination of water. Nuclear energy parks, with co-location of all fuel cycle facilities, are again envisaged.

FUEL CYCLE

The technical problems of the fuel cycle, at least for the power reactors in operation today, have been solved for each step of the fuel cycle. A characteristic of the nuclear fuel industry is that its product is for one use only and the number of customers is limited to other industries in the fuel cycle.

There are close inter-relations between such elements of the cycle as demand for uranium, enrichment and reprocessing services. These factors represent a strong technical and commercial incentive for integrated planning of the fuel cycle. Furthermore, it has been demonstrated, especially by recent developments, that the nuclear fuel industry cannot be looked at exclusively from a commercial point of view, but many political aspects must be taken into account because at least some steps can be mis-used. Because of this feature, as well as of the environmental implications involved, the industry must accept strict national and international controls. Consequently, the direct or indirect governmental actions will continue to be of essential importance and provide decisive assistance in tackling short-term issues which, if they are not resolved, would leave little opportunity to consider long-term problems.

There are long lead times for new capacities and there have been many instances of inadequate long-term planning in the past. This provides an almost ideal structural setting for violent fluctuations in price and capacities as, for instance, the recent history of uranium supply bears out. Still, this same example shows an industry which, it has been stated at least from one quarter, in the future can expand quickly to meet foreseeable demands provided that an adequate economic and political climate and an adequate basis for long-term planning exists.

Beginning at the front end of the fuel cycle, a steep increase in uranium demand is anticipated, particularly in view of the reduced prospects for recycling uranium and plutonium, and this demand could lead to the exploitation of low-grade uranium deposits. Factors limiting their exploitation now include production costs and environmental restraints. Studies indicate, however, that given an incentive these low-grade ores might be economically recoverable within ten years. Further research and development is needed in exploration methods to locate deep deposits. Recovery of uranium from sea water does not seem to be of economic interest for some time.

Because of uncertainties at other stages of the fuel cycle – reprocessing policy, for example – our ability to predict how much uranium we will need when is limited. This may, in future, have disrupting effects on the energy market. International planning could avoid a scarcity of uranium; but so far, we have been unable to achieve that kind of cohesion.

Experience during more than a decade of light-water and heavy-water power reactor operation has shown a high degree of reliability of uranium and mixed oxide fuel elements which has been achieved through close co-operation of fuel suppliers and utilities. The failure rates of light- and heavy-water reactor fuel elements were about comparable and lie today approximately around 0.03 percent. This failure rate is low, but efforts are being made to decrease this rate even further.

Enrichment capacities will be adequate up until 1985, but new capacity and new technologies need very long lead times. This technology certainly is the one which has been most guarded by secrecy in individual countries. But this has not resulted in non-

The International Conference on Nuclear Power and Its Fuel Cycle was opened on 2 May 1977 by the President of the Federal Republic of Austria, Dr. Rudolf Kirchschläger. Here is an excerpt from his opening address:

"The world expects great things from this conference, in other words from you, the participants who are making an active contribution to it. Great responsibility rests on your shoulders, particularly great because it encompasses generations yet to come. A 'No' to nuclear energy, seemingly the simplest of answers, would surely be a true answer only if other energy sources could be made available in sufficient quantity and with adequate guarantees of protection for the environment; or, alternatively, if we were sincerely convinced that the world could be maintained static in, say, the situation prevailing in the year 1950 for all of future time, and that further development could be ruled out. But none of us can honestly believe in this latter possibility: apart from anything else, all the resolutions of the United Nations concerning economic development in the emergent countries suggest that the contrary is true.

"Please believe me, then, that it is not just an expression of courtesy but the utterance of an honest, profoundly felt hope, when I wish you success in your deliberations and the achievement of results which will help mankind to judge nuclear energy properly, and which, above all, will provide reliable guidance for those who are called upon to make fundamental decisions in the energy sector."

proliferation of the technology as clearly shown by the many papers on independent successful ventures to provide enriched uranium for domestic civil power needs presented at this conference. The new enrichment process using chemical exchange reactions announced at the conference may have a bearing on the proliferation problem.

The technology of reprocessing has been worked out satisfactorily in many countries. At the Fourth Geneva Conference, a surplus in reprocessing capacity was expected. Today, a shortage has developed which is leading to the long-term storage of spent fuel elements. Reprocessing is regarded by most countries as necessary for making the best use of the energy potential of uranium and as the first step towards long-term waste management.

The use of plutonium has been demonstrated in both thermal and fast reactors and enough plutonium would be available for the introduction of fast breeders. At the same time, the handling and transport of large quantities of plutonium give a strong incentive for co-location of fuel cycle facilities.

The announced plans for expanding fuel cycle services vary greatly between different countries. There are still some common features in all these, including:

(1) a strong desire to obtain guaranteed supplies for fuel cycle services, and

(2) a desire to establish and maintain industrial capability.

While the investment required for the fuel cycle industries as a whole is relatively small as compared with the power plants served, perhaps of the order of 10 percent, some of these industries, such as enrichment and reprocessing plants, individually require investments of a large magnitude. The availability of such financing will finally depend on confidence in the long-term stability of the industry. Industrial enterprises for uranium production, enrichment and reprocessing, whether private or quasi-governmental, must obtain financing for long periods of investment and operation. They have, therefore, little choice other than to seek long-term contracts with the owners of the facilities to be served. These contracts are now also shaped in new forms calling for a closer commercial co-operation between suppliers and buyers in different countries.

The nature of the industry, the size of some facilities, and the need for trade in services and supplies mean that few countries can really be self-sufficient. This in itself will provide an incentive towards multinational and international management and control of fuel cycle facilities and services.

Several proposals have been made for the IAEA to play a stronger role in the fuel cycle, particularly in its tail end. The Agency's study of regional fuel cycle centres can be regarded as a beginning for further activities, the extent and scope of which will have to be carefully considered. Such a scope could include, for instance, advice and guidelines for long-term storage of spent fuel in the case of an open-ended fuel cycle but could range into expansion of our present studies of alternative fuel cycles over the next several years.

ENVIRONMENTAL ASPECTS

Assessments shown that the applications of principles recommended by the International Commission for Radiological Protection ensure that the exposure of workers and of the general public arising from the nuclear fuel cycle facilities can be kept to an acceptable level now and in the future. In spite of this, work continues on an international basis on the assessment of occupational and public exposure and in the setting of limits on releases to the atmosphere and to international water systems. Compared to this effort, work with regard to the consequences of fossil-fuel uses, is in the early development stage.

A review of international experience in the transportation of radioactive materials indicates that hundreds of tons of spent reactor fuel and other radioactive material have been successfully transported to date under the authority of national and international regulations which are almost universally based on the Agency's transport regulations. To date, no person has received any injury from the radioactive properties of this material either in the normal transportation process, nor from those transportation accidents that, inevitably, have occurred.

In anticipation of the larger amounts of spent fuel and other radioactive materials that will be shipped in future, current work in this field centres on the development of larger shipping containers and the demonstration of their integrity under conceivable severe accident conditions.

At the first plenary session of the conference, a message from the Secretary-General of the United Nations was delivered by Vladimir Baum, Director of the UN Centre for Natural Resources, Energy and Transport.

"Mr. Chairman, before commencing my presentation, allow me first to convey to the conference the greetings of the Secretary-General of the United Nations, Dr. Kurt Waldheim. Due to pressing commitments, which you will well understand, he has unfortunately been unable to come to Salzburg himself and has therefore requested me to express to you, Mr. Chairman, and to all the distinguished participants gathered here, his best wishes for the succes of this important and timely undertaking, which should help us all to obtain a better understanding of the very topical problems surrounding the future of nuclear technology. Your conference, as it follows those that took place on such subjects as the environment, population, food, human settlements and most recently water, and preceding the United Nations Conference on Science and Technology, is an important part of the overall effort by the whole United Nations system to provide the broadest expert forums for exchange of information, transfer of technology, for the fostering of co-operation among member countries, which will hopefully make it possible for the world to move towards a more prosperous and safer future. Mr. Waldheim, is confident that your conference is an essential link in this chain and looks forward with great interest to hearing about your achievements."

National programmes for the management of radioactive wastes are all investigating the possibilities of vitrifying the liquid, highly radioactive waste resulting from reprocessing and disposing of the product in geological formations.

Technology is now available for the safe treatment, conditioning and storage of essentially all the hazardous radioactive waste products from the nuclear fuel cycle. What is now required is the practical demonstration of large-scale geological disposal.

The possiblity of international co-operation in the demonstration of waste disposal concepts, especially with a view of having regional disposal facilities for the long-lived wastes, was raised. Unfortunately, it appears that the time for political action on this concept is not yet ripe.

More attention must be paid to the eventual decommissioning of nuclear fuel cycle facilities. Decommissioning plans and procedures should be taken into account during the design and licensing stages and be approved by the licensing authorities. In this respect, it has been consistently pointed out at this conference, that national authorities should now set guidelines for the financial arrangements and responsiblities to cover the future costs of waste disposal and decommissioning.

In over 1400 reactor-years of commercial power reactor operation, no accident leading to a radiation-related disability has occurred – a record that is unparallelled in any other modern large-scale industry. In spite of this record, improved safety features continue to be developed and incorporated in reactors. To help attain a high international standard in the field, Member States have supported the IAEA in working out safety codes and guides for thermal power plants.

The fabrication and reprocessing of irradiated fuel present a wider range of safety problems than any other part of the fuel cycle because of the large amounts of radioactive material present. However, the application of nuclear power plant safety criteria should provide adequate protection for these plants.

NUCLEAR POWER IN DEVELOPING COUNTRIES

It has become apparent from the numerous papers presented by participants from the Third World that their nuclear programmes now show a high degree of maturity. It was also evident that in establishing their nuclear power programmes, full account had been taken of alternative energy sources available, including solar energy, the use of which is of interest to a number of developing countries. The conclusion, however, was that for large-scale electricity production, in the absence of indigenous coal, nuclear power and imported oil were the only available choices. Small-scale, local energy needs may be filled by solar energy or biomass.

No longer does the concern of these countries centre on basic aspects of nuclear energy, but rather on the more practical problems of how to initiate nuclear programmes and how to successfully implement on-going nuclear programmes. It is obvious that the suppliers and recipients of nuclear technology must work together to give nuclear power a meaningful role in the developing world.

At the present time, operating nuclear plants in five developing countries represent less than one percent of the installed electrical capacities of all developing countries and only about three percent of the world nuclear capacity. Twelve other developing countries have nuclear plants under construction or planned for operation by 1985 with an aggregate capacity of about 28 000 MWe. Thus the developing world's share of total world nuclear capacity will increase to about nine percent by 1985.

Many problems will have to be overcome, one of the most difficult of which is financing, particularly the foreign currency requirements. At an informal meeting last week outside this conference between a number of bankers, industrialists and utility representatives, serious thought was given to this problem and a continuation – in one form or another – of the discussion is under consideration.

Other requirements include skilled manpower, adequate local industrial and engineering infrastructure, the need for a free nuclear market, access to advanced technology transfer, the availability of nuclear power plants in the required sizes, and an ensured supply of nuclear fuel.

Of particular importance was that a number of papers showed how the developing countries can learn from each other. Some novel approaches were suggested, such as specially developed organizational structures for implementing nuclear programmes, joint ventures

"Mr. Director General: On the occasion of the opening of the IAEA International Conference on Nuclear Power and Its Fuel Cycle, I send to you and to all the delegates in attendance my personal best wishes for a successful meeting. The IAEA can be proud of its service to the world in bringing the peaceful benefits of nuclear energy to many nations and in protecting the world from the dangers of the diversion of nuclear energy to military purposes. This large conference in Salzburg is yet another example of the Agency's value in bringing together the best scientific minds to address these questions of vital importance. I am pleased that a number of important departments of the United States Government are represented as well as a large group from our nuclear industry and our universities. As I have recently announced, the United States intends to undertake broad consultations with supplier and recipient countries on a wide range of international approaches and frameworks that I believe will permit all nations to achieve their energy objectives while reducing the spread of nuclear explosive capability. This Conference can make a significant contribution to this effort."

Message from President Jimmy Carter of the USA

as a means of comprehensive technology transfer, and the expansion planning of small electrical systems including planned load shedding to allow the incorporation of relatively large units.

Nuclear manpower development is of particular importance to those developing countries about to embark on nuclear programmes. The unavailability of trained personnel at a time when they are needed can constitute a major constraint. The IAEA has for several years recognized the importance of this problem and has greatly intensified its efforts to provide opportunities for manpower development. Foreign training programmes, on-the-job training, and the changing role of nuclear research centres in developing countries are also helping to alleviate the situation.

One aspect stood out quite clearly, namely, that there is a clear trend toward gradual but continuous increase of national capabilities in the construction and implementation of nuclear power projects with an attendant increase in the indigenous contribution of equipment, materials and engineering.

SAFEGUARDS

One of the conclusions which appeared repeatedly throughout the discussions on nuclear fuel cycle problems was a recognition of the need for further strengthening the international non-proliferation regime in the sensitive areas of the cycle, both in terms of its universal acceptability and improvements of political and technical measures aimed at preventing proliferation. This is a condition for ensuring internationally available fuel cycle services.

Emphasis has been placed on the fact that the ultimate responsibility for effective international safeguards rests with the IAEA. Thus, notwithstanding the requirement for improved national and multinational systems of nuclear materials accountancy and control, the *sine qua non* of effective international safeguards is independent verification by the IAEA of compliance with the provisions of safeguards agreements concluded pursuant to the Non-Proliferation Treaty (NPT) and to the Statute of the IAEA. This independent verification is the basis of the IAEA safeguards system and this responsibility cannot be transferred to any other authorities.

Experience in safeguards implementation and work on a number of technical developments in safeguards was reported and reviewed, *inter alia,* the integrated material accountancy system and development of "real time" material control systems in reprocessing facilities. The need for extensive use within the Agency's safeguards of containment and surveillance methods was emphasized. Isotopic correlation techniques, as well as progress in working out safeguards criteria and modelling techniques in evaluating the effectiveness of safeguards were reviewed.

Besides endeavours for full fuel cycle safeguards in all non-nuclear-weapon States, room was clearly seen for introducing measures, supplementary to the existing international safeguards, for example, regional or multinational fuel cycle centres, internationally controlled plutonium storage and international conventions governing physical security arrangements, especially relating to international transfers of nuclear material. The implementation of these measures would require new, unconventional political, economic and organizational solutions which would have to be worked out. There seems to exist an awareness, however, that character and scope of problems, which further development of nuclear fuel industry will bring, make it necessary to introduce gradually these unconventional solutions. At the same time, work should be continued on processes which might in themselves ease the safeguards problem and contribute to non-proliferation by minimizing the access to large quantities of weapons-grade materials.

It was stressed that in order to solve the fundamental problems of non-proliferation, political considerations are as important as technical or legal ones — in fact, these two aspects are complementary. Let me recall that these problems have been in the mind of scientists and technicians for a long time and it is encouraging to note that they are now being given urgent attention at the highest political level.

CONCLUSION

Before closing, I would like to digress from my summing up to express my personal views on some matters that have come up during the conference. I was asked by a journalist what I considered to be the IAEA's greatest achievement and greatest failure during my time in office. The first question is easy. For me, the greatest achievement of the IAEA has been to merit the confidence expressed by the world community when it invested the Agency with the safeguards functions under the NPT. I attach greatest importance to the aims of that Treaty and believe that international safeguards can be developed to eliminate the fear of the acquisition of nuclear weapons under the cloak of a peaceful nuclear programme. To this I must add however, the hope that the non-proliferation regime will eventually be accepted by all countries. The second question is more difficult to answer as the failures have been many. A first disappointment has been the failure to provide enough

sources for technical assistance to developing countries. I am thinking here not only of assistance in the nuclear power field, but also in applications of nuclear technology in agriculture and medicine, for example.

Secondly, although this goes beyond the scope of the Agency's duties, I feel that we also share the responsibility for having failed to convey to the peoples of the world the message that nuclear energy represents no larger, and indeed often smaller, risks than many other technologies that have been accepted by modern society. This message is, however, difficult to get across through the news media. As Lord Beaverbrook once said, "Good news is bad news and bad news is good news". It will be unfortunate if the "good news" of nuclear power will only finally come across as the "bad news" of energy shortages and economic dislocations is reported.

In the conference we have listened to a wide spectrum of views, including the pessimistic one that the only way to avoid the problems of non-proliferation is to give up nuclear power altogether. We have heard the views of concerned citizens' groups, outside our technological and governmental circles, who are seeking to participate in the decision-making process in this area of social and political, as well as technological and economic importance. The IAEA will continue to do its part to keep the debate open.

As the conference draws to an end, I leave it to participants to judge whether it has achieved its objectives, of which the principal one was to give a comprehensive overview of the status, prospects and problems of the various components of the nuclear fuel cycle and their inter-relationship. I think we all agree that the conference was timely and that the subjects selected for discussion could hardly have been more topical.

I would once again like to express my thanks to the Scientific Advisory Committee for its wise guidance in helping us to select the right topics and to strike a balance between them, to the invited speakers, to the participants from Member States and international organizations who contributed papers to the conference, to those who have participated in the discussions, and to all of you who have constituted an interested and critical audience. I am sure that I express the sentiments of all participants in thanking again the Government of Austria and the Province and City of Salzburg for their generous help and hospitality, and I am sure you share my appreciation of the messages from the Presidents of Austria and the United States and the Secretary General of the United Nations.

Many thoughtful proposals and recommendations have been addressed to the Agency during the course of the conference. It is too early to comment on them but I would like to give an assurance that they will be carefully considered by the Secretariat and will be reflected, if feasible, in the programmes to be submitted to the Board of Governors and General Conference.

Let me conclude by stating my personal conviction that nuclear energy in its present form and later in a more sophisticated and vastly more energy-efficient transformation will realize its promise and make its proper contribution to society. Of this I have no doubt.

The only open question is one of timing, and here the conference has sounded a warning note against delays. We must move forward with all deliberate speed if we are to avoid the possiblity of a world-wide energy crisis – a crisis of inadequacy – before the end of this century.